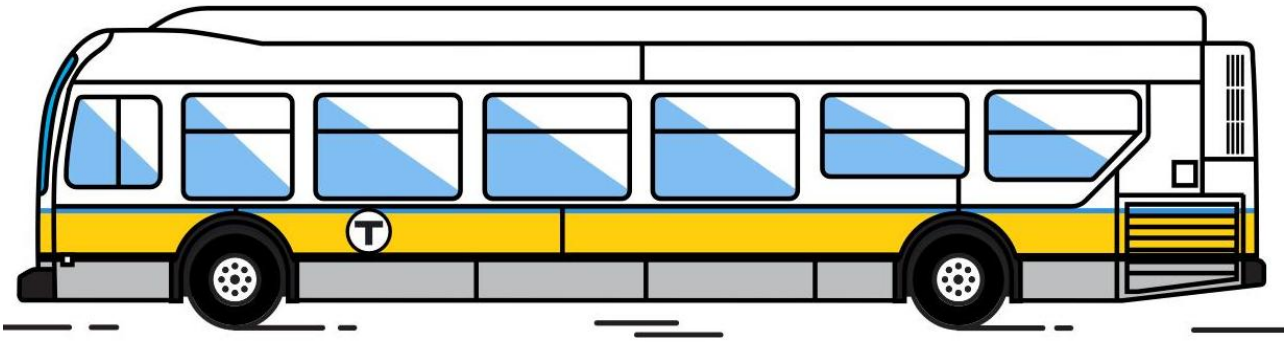
TECHNICAL SPECIFICATION

FOR THE

PROCUREMENT OF 40 FT LOW-FLOOR BATTERY ELECTRIC BUSES



April 24, 2022

Massachusetts Bay
Transportation Authority
Vehicle Engineering
Boston, Massachusetts

Technical Specification
No. VE21-054

TABLES

FIGURES

ATTACHMENTS

TECHNICAL SPECIFICATION: VE21-054

I. GENERAL

TS 1. Scope and General Design Requirements

These Technical Specifications and TS Attachment 1 through TS Attachment 10, and RFP 1F-22 and RFP Attachments, define requirements for heavy-duty Battery Electric transit buses (BEB).

The Technical Specification provides requirements for the Base order configuration and additional requisites for Streetside Boarding Option buses.

Specific contracting mechanisms shall utilize these specifications to define the requirements for the bus design and bus order quantities. Buses shall have a minimum expected service life of fourteen (14) years or 500,000 miles, whichever comes first, and are intended for the widest possible spectrum of passengers, including children, adults, the elderly, and people with disabilities.

TS 1.1 FMVSS and Legal Requirements

The Contractor shall comply with all applicable Federal, State, and Local regulations, including but not limited to FMVSS, ADA, EPA and all current applicable FMCSR and NFPA regulations, in effect for the bus at the date of manufacture. Local regulations are defined as those below the state level. In the event of any conflict between the requirements of this Specification and any applicable legal requirement, then the legal requirement shall prevail.

Massachusetts Department of Public Utilities (DPU) 220 CMR 155.04 states: *The Federal Regulations, 49 CFR 390 through 397, including Sub-chapter B, Appendix G, as appearing in 155.04, or as may be revised in the Code of Federal Regulations, as related to the inspection of Commercial Motor Vehicles or any activity related thereto, are hereby adopted as the Regulations of the Department of Public Utilities. Said regulations are applicable to vehicles transporting more than 16 persons including the driver. In the event of any conflict between these regulations and any other regulations or law of the Commonwealth of Massachusetts, the stricter more stringent standard shall apply.*

The Contractor shall submit FMVSS certificates of compliance or waiver from appropriate regulatory agency at the Pre-Production Meeting **(CDR 8).** The Contractor shall deliver a copy of the Altoona (PTI) Test Report and Passing Score for the bus with the Bid Proposal, or no later than prior to the Kickoff Meeting. The Contractor must comply with all provisions of CFR 49, including Buy America Pre Award and Post Delivery Audit requirements. Upon request, the Contractor shall provide detailed testing reports and scoring to verify compliance with FMVSS requirements for any and all major sub-systems.

Notwithstanding, anything in the Contract to the contrary, it is understood and agreed to by the Contractor that the Massachusetts Bay Transportation Authority, herein referred to as the Authority, provided the Technical Specification for the sole purpose of describing in general terms the performance required from each bus, each bus's systems, and the discrete subsystems, that make up the bus. The specification provided by the Authority does not in any way constitute a design of the bus or of such subsystems or discrete components. It is further understood that the Authority makes no representations regarding the Technical Specifications. It shall be incumbent on the Contractor to verify the accuracy of the Technical Specifications prior to the time of the bid.

This Technical Specification is intended to leave the Contractor free to provide its own detailed design for the basic vehicle and the vehicle's ancillary equipment. The Contractor shall assume complete and overall responsibility for the design and satisfactory operation of the vehicle and the vehicle's subsystems or component parts. The Contractor's responsibility includes, but is in no way limited to, ensuring that the design and manufacture of the vehicle and the vehicles component parts are appropriate, coordinated, compatible, and that they perform correctly throughout the service life of the vehicle, whether together or individually.

The Contractor shall ensure that each manufacturer of major items of equipment (for example, energy storage system, traction motors, brakes, heat and air conditioning systems and controls, doors and controls, seats, lighting, etc.) has a complete copy of the Technical Specifications. Sub-suppliers shall approve of and sign-off on the Contractor's specific application of their components. Proof of sub-suppliers installation approval shall be provided to the Authority. **(CDR 18)**

TS 1.2 MBTA Safety and Regulatory Requirements

The Contractor shall incorporate appropriate Safety Certification functions, processes and activities to ensure that all hazards have been effectively identified, analyzed, and eliminated or mitigated to the lowest practical level of risk. Design changes or modifications that may impact safety shall be defined, appropriately documented, and submitted to the Authority for review and approval.

In addition, the Contractor shall comply with all MBTA Safety Certifications and regulatory requirements in effect at the time the NTP is issued as defined within the Contract documents. The Contractor shall collaborate with MBTA to ensure that safety concerns and hazards have been effectively addressed, eliminated, or mitigated, to the lowest practical level of risk.

The Contractor's Safety Plan shall also,

1. Detail their pandemic response measures including policies, practices, PPE, and cleaning protocols.
2. Provide Battery Electric Bus (BEB) system specific safety procedures and considerations
3. Include safety certification design validation process for all safety critical designs, changes, and modifications
4. Include bus safety related systems theory of operation (e.g. interlock systems)
5. Address all aspects of the requirements of ESS System Safety (TS 8.6)
6. Detail their process to address, eliminate, or mitigate safety concerns and hazards to the lowest practical level of risk
7. Detail the qualification of multiplex and control systems per ISO 26262
8. Provide a cybersecurity threat analysis and risk assessment of the full vehicle per the latest revision of ISO/SAE 21434

The Contractor shall develop and submit a Safety Plan for this project to be submitted during the Pre-Production meetings **(CDR 7)**.

TS 1.3 Testing of New Bus Models

The Contractor agrees to comply with 49 USC 5323(c) and FTA's implementing regulation at 49 CFR Part 665 and shall perform the following:

1. In each application to FTA for the purchase or lease of any new bus model, or any bus model with a major change in configuration or components to be acquired or leased with funds obligated by the FTA, the recipient shall certify that the bus was tested at the Bus Testing Facility and that the bus received a passing test score as required in this part. The recipient shall receive the appropriate full Bus Testing Report and any applicable partial testing report(s) before final acceptance of the first vehicle.
2. A manufacturer who releases a report under Paragraph 1 above shall provide notice to the operator of the testing facility that the report is available to the public.
    a. If the manufacturer represents that the vehicle was previously tested, the vehicle being sold should have the identical configuration and major components as the vehicle in the

test report, which shall be provided to the recipient prior to recipient's final acceptance of the first vehicle. If the configuration or components are not identical, the manufacturer shall provide a description of the change and the manufacturer's basis for concluding that it is not a major change requiring additional testing.

TS 2. Definitions, Acronyms, and Abbreviations

The following are definitions of special terms used in this document:

Agency Operating Profile: The operational requirements under MBTA-specific operating environment that the bus must be able to achieve.

Alternative: A service proven alternate to the specified bus configuration subject to approval by the Authority.

Ambient Temperature: The temperature of the surrounding air. Unless otherwise specified, ambient temperature for testing purposes must be between 10° C (50° F) and 38° C (100° F).

Analog Signals: A continuously variable signal that is solely dependent upon magnitude to express information content.

As-Built: Drawings and documentation of how the bus was actually constructed. Not to be confused with design or concept drawings and documents.

Audible Discrete Frequency: An audible discrete frequency is determined to exist if the sound power level in any 1/3-octave band exceeds the average of the sound power levels of the two adjacent 1/3-octave bands by 4 decibels (dB) or more.

Authority (or Agency): Massachusetts Bay Transportation Authority (MBTA)

Authorized Signer: The person who is executing this Contract on behalf of the Contractor, and who is authorized to bind the Contractor.

Baseline Design Configuration: The design configuration defined at the time of Pilot bus approval and shall become the basis for the production bus configuration under this Contract.

Battery Compartment: Low-voltage energy storage, i.e. 12/24 VDC batteries.

Battery Electric Bus (BEB): A bus that uses it's on-board Energy Storage System to provide a source of energy to provide power to the electric drive/traction motor(s). The BEB primarily relies on a stationary charging system to recharge the batteries between service trips.

Battery Management System (BMS): Monitors energy, as well as temperature, cell or module voltages, and total pack voltage. The BMS adjusts the control strategy algorithms to maintain the batteries at uniform state of charge and optimal temperatures. In addition, this system shall protect the batteries from damage due to low state of charge.

Braking Resistor: Device that converts electrical energy into heat, typically used as a retarder to supplement or replace the regenerative braking.

Burst Pressure: The highest pressure reached in a container during a burst test.

Bus: A complete vehicle that conforms to these Technical Specifications and is ready to operate.

Capacity (fuel container): The water volume of a container in gallons.

Cells: Simplest discrete component of the battery storage system, such as a battery or a capacitor.

Charging Equipment: The equipment that encompasses all the components needed to convert, control and transfer electricity from the grid to the vehicle for the purpose of charging batteries. May

include chargers, controllers, couplers, transformers, ventilation, etc. See Electric Vehicle Supply Equipment (EVSE).

Charging Interface: The equipment and/or coupler used to create a connection between the charging equipment and the vehicle for the purpose of recharging a vehicle's batteries.

Charging Station: The location that houses the charging equipment connected to a utility's electric service to provide electricity to a vehicle's battery system through a charging interface.

Class 1 Failure (physical safety): A failure that could lead directly to passenger or operator injury and represents a severe crash situation.

Class 2 Failure (road call): A failure resulting in an en route interruption of passenger service. Service is discontinued until the bus is replaced or repaired at the point of failure.

Code: A legal requirement.

Competitive Range: The range of proposals that are identified as the most highly rated, unless the range is further reduced for purposes of efficiency.

Contract: RFP No. 1F-22

Contractor's Drawings: Items such as general arrangement drawings, detail drawings, graphs, diagrams, and sketches that are prepared by the Contractor to detail its work.

Contracting Officer: The person who is executing this Contract on behalf of the Authority and who has complete and final authority except as limited herein.

Contractor: The successful Proposer who is awarded a Contract for providing all buses and equipment described in the Contract documents.

Converter: A module that changes AC voltage to DC voltage

Curb Weight: Weight of vehicle, including maximum fuel, coolant; and all equipment required for operation and required by this Specification, but without passengers or driver.

Days: Unless otherwise stated, "days" shall mean calendar days.

dBA: Decibels with reference to 0.0002 microbar as measured on the "A" scale.

DC to DC Converter: A module that converts a source of direct current from one voltage level to another.

Default Configuration Bus: The bus described if no alternatives are selected.

Defect: Patent or latent malfunction or failure in manufacture, installation or design of any component or subsystem.

Design Life: Shall mean the same as "service life"

Design Operating Profile: For design purposes, the simulated MBTA Agency Operating Profile

Destroyed: Physically made permanently unusable.

Deviation: Variance from a requirement or specification that does not adversely affect the form fit or function of the part or system. Deviation from the technical specifications requires Authority approval.

Discrete Signal: A signal that can take only pre-defined values, usually of a binary 0 or 1 nature, where 0 is battery ground potential and 1 is a defined battery positive potential.

Driver: Shall mean the same as operator

Driver's Eye Range: The 95th-percentile ellipse defined in SAE Recommended Practice J941, except that the height of the ellipse shall be determined from the seat at its reference height.

Due Date: The date and time by which Proposals must be received by the MBTA as specified in Contract Section.

Electrical Pack: An electrical equivalent of a collection of cells or modules or physical sub-packs forming the highest-level energy storage system. Often multiple physical sub-packs are connected in series, and these may also be connected in parallel.

Electric Vehicle Supply Equipment (EVSE): The conductors, including the ungrounded, grounded and equipment grounding conductors, the electric vehicle connectors, the attachment plugs, and all other fittings, devices, power outlets or apparatuses installed specifically for the purpose of delivering energy from the premise's wiring to the electric vehicle.

End of Life: A condition reached when an energy storage system fails to meet specified capacity, power, or function in specified use conditions. End of Life shall mean the same as 'Warrantable End of Life'.

Energy Density: The relationship between the weight of an energy storage device and its power output in units of watt-hours per kilogram (Wh/kg).

Energy Storage System (ESS): A component or system of components that stores energy and for which its supply of energy is primarily an off-vehicle energy source,

Equal: Whenever the words "equal", "equivalent" or "approved equal" are used in connection with make or quality of material or equipment, the proposed alternative shall be service proven, and functionally compatible with an of equal or better quality than the item it is proposed to replace. The Technical Project Manager's decision as to whether any material or equipment proposed is equal to that specified shall be binding and final on both the Contractor and the Authority.

Extended Warranty: A warranty available for purchase above the standard warranty.

Fatigue Failure (Corrosion Fatigue): The mechanical degradation of a material under the joint action of corrosion and cyclic loading.

Failure Rate: The frequency of failure, expressed as failures per mile. Failure rate is the mathematical reciprocal of Mean Mileage Between Failures (MMBF).

Finite Element Analysis (FEA): A structural analysis model using a recognized computer program that shall be utilized to establish the structural adequacy of the bus body, chassis, frame, and other structural parts.

First Article Acceptance Inspection (FAI): The physical examination, acceptance, and commercial testing of, and acceptance by the Authority, of an initial part, major assembly, subassembly, system, subsystem, apparatus or material, manufactured or assembled by either the Contractor or Subcontractors.

Fuel Line: The pipe, tubing, or hose, on a vehicle, including all related fittings, through which fuel passes.

Fusible Material: A metal, alloy, or other material capable of being melted by heat.

Fire Resistant: Materials that have a flame spread index less than 150 as measured in a radiant panel flame test per ASTM-E 162-90.

Fireproof: Materials that will not burn or melt at temperatures less than 2000° F.

Free Floor Space: Floor area available to standees excluding the area under seats, area occupied by feet of seated passengers, the vestibule area forward of the standee line, and any floor space indicated

by manufacturer as non-standee areas, such as the floor space "swept" by passenger doors during operation. Floor area of 1.5 sq. ft. shall be allocated for the feet of each seated passenger protruding into the standee area.

Fuel Management System: Fuel system components that control or contribute to air fuel mixing and metering, and the ignition and combustion of a given air-fuel mixture.

GAWR (Gross Axle Weight Rated): The maximum total weight as determined by the axle manufacturer, at which the axle can be safely and reliably operated for its intended purpose.

Generator (Electric): A device that converts mechanical energy into electrical energy.

Gross Load: To be calculated as the sum of 200 lbs. for the driver, plus 600 lbs. for each wheelchair position, plus 150 lbs. for each designed passenger seating position and for each 1.5 sq. ft. of free floor space.

GVW (Gross Vehicle Weight): Curb weight plus gross load.

GVWR (Gross Vehicle Weight Rating): The maximum total weight as determined by the vehicle manufacturer, at which the vehicle can be safely and reliably operated for its intended purpose. GVWR shall not be less than GVW.

Heat Exchanger: A device used to transfer heat from a fluid on one side of a barrier to a fluid on the other side without bringing the fluids into direct contact. Examples of heat exchangers include but are not limited to radiators, heater cores, condensers, and evaporators.

High Voltage (HV): Electric component or circuit with a working voltage greater than 30VAC (rms) and 60VDC (ISO 6469-3), also referred to as "Class B Voltage".

Hose: Flexible line.

Inspector: (also Resident Inspector) The person or firm designated by the Authority as its quality assurance representative. A representative(s) of the Authority assigned to inspect materials and workmanship.

Inverter: A module that changes DC voltage to AC voltage.

Labeled: Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization, which is acceptable to the authority having jurisdiction and concerned with product evaluation, which maintains periodic inspection of production labeled equipment or materials, and by who's labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Lead Bus: See Pilot Bus.

Leakage: Release of contents through a defect or a crack. See *Rupture*.

Line: To include all pipes (rigid lines), tubing (semi-rigid lines), and hose (flexible lines), that carry fluids.

Liner: Inner container to which an overwrap is applied.

Local Regulations: Regulations below the state level.

Low-Floor Bus: A bus that, between at least the front (entrance) and rear (exit) doors, has a floor sufficiently low and level so as to remove the need for steps in the aisle between the doors and in the vicinity of these doors.

Low Voltage (LV): Electric component or circuit with a maximum working voltage of less than 30 VAC (rms) or 60 VDC (ISO 6469-3), also referred to as "Class A Voltage".

Maintenance Manuals: Any time the term "Maintenance Manuals" is used in this specification, it is intended that it shall include detailed instructions for servicing and maintaining the bus and all components, to include ladder logic, electrical prints, pneumatic diagrams, and hydraulic diagrams.

Mean Mileage Between Failures (MMBF): The mean operating mileage between independent failures.

Metallic Hose: A hose whose strength depends primarily on the strength of its metallic parts; it can have metallic liners or covers, or both.

Module: A collection of cells forming a physical and electrical subassembly contained within an enclosure.

Motor (Electric): A device that converts electrical energy into mechanical energy.

Motor (Traction): An electric motor used to power the driving wheels of the bus.

Nameplate Capacity (also known as Rated Capacity): The advertised energy storage system capacity expressed in kWh when new. The advertised capacity includes the electrical energy in the ESS that is not accessible due to battery protection.

Pack: A collection of cells or modules, described on the basis of electrical or physical attributes, to include Electrical Pack and Physical Pack.

Pass-Through Warranty: A warranty provided by the Contractor but administered directly by the component Supplier.

Physical Layer: The first layer of the seven-layer International Standards Organization (ISO) Open Systems Interconnect (OSI) reference model. This provides the mechanical, electrical, functional, and procedural characteristics, required to gain access to the transmission drive medium (e.g., cable) and is responsible for transporting binary information between computerized systems.

Physical Pack: An enclosure consisting of a collection of cells or modules at a location or multiple locations. Physical packs differ from electrical packs, as they are defined by layout rather than electrical equivalent.

Pilot Bus(es): The first complete bus manufactured by the Contractor to establish the base line for production configuration. The Pilot Bus shall not be used to complete Altoona or Shaker Table testing.

Pipe: Rigid, nonflexible line.

Pressure Relief Device (PRD): A pressure and/or temperature activated device used to vent a pressurized vessel as a safety precaution.

Proof of Concept: A phase in development in which proposed bus, individual systems, or components, are tested to explore and demonstrate the feasibility of the concept.

Power: Work or energy divided by time

Power Density: Power divided by volume or area.

Proof (used as a suffix): Apparatus is designated as "splash proof," "dustproof," etc., when so constructed, protected, or treated that its successful operation is not interfered with when subjected to the specified material(s) or condition(s).

Proposal: A promise, if accepted, to deliver equipment and services according to the underlying solicitation of the Authority documented using the prescribed form in the solicitation, including any Proposal or BAFO.

Proposer: A legal entity that makes a Proposal.

Propulsion System: System that provides propulsion for the vehicle proportional to operator commands. Includes, as applicable, traction motors, energy storage system (ESS), and system controllers including all wiring and converter / inverter.

Real-Time Clock (RTC): Computer clock that keeps track of the current time.

Regenerative Braking: Deceleration of the bus by switching motors to act as generators, which returns vehicle kinetic energy to the energy storage system.

Related Defect: Damage inflicted on any component or subsystem as a direct result of a separate Defect.

Reliability: The probability of performing a specified function without failure and within design parameters for the distance, under actual operating conditions.

Request for Approved Equal: A formal submission by the Contractor requesting the use of an alternative product for the Authority's consideration.

Rupture: Sudden and unstable damage propagation in the structural components of the container resulting in a loss of contents. See Leakage.

Safe: The condition in which passengers, operators, or maintenance personnel are secure from threat or danger, harm, or loss arising from improper design, manufacture, assembly, malfunction, or failure of the bus or any of its components or systems.

Seated Load: 150 lbs. for every designed passenger seating position, plus 200 lbs. for the bus driver, plus 600 lbs. for each wheelchair position.

SLW (Seated Load Weight): Curb weight plus seated load.

Serial Data Signals: A current loop-based representation of ASCII or alphanumeric data used for transferring information between devices by transmitting a sequence of individual bits in a prearranged order of significance.

Service Proven: to have been used in continuous passenger service on no less than 100 buses, for no less than three years and 75,000 miles in an operating environment similar to the Authority, and with zero warrantable defects or failures.

Solicitation: The Authority's request for proposals.

Special Tools and Test Equipment: Tools and test equipment not normally stocked by the Authority.

Special Listings: Technical Documentation regarding the Operation and Maintenance of a vehicle or the vehicle subcomponents which is not provided as part of the OEM or OEM vendor Maintenance and Parts Manuals

Specification: A particular or detailed statement, account or listing of the various elements, materials, dimensions, etc. involved in the manufacturing and construction of a product.

Standard: A firm guideline from a consensus group such as ISO, SAE, NFPA, ANSI etc., . The Contractor shall be responsible for confirming and adhering to the latest revision of all Standards referenced.

Standee Line: A line marked across the bus aisle to designate the forward area that passengers may not occupy when the bus is moving.

State of Charge (SoC): Dynamic measurement of the quantity of electric energy remaining in the energy storage system relative to the maximum rated kWh capacity of the ESS expressed in a

percentage. A full SoC indicates that the energy storage system cannot accept further charging from the facility charging stations or the regenerative braking system.

State of Health (SoH): Dynamic measurement of the energy storage system capacity relative to a new ESS nameplate/advertised capacity

Stress Loops: The "pigtails" commonly used to absorb flexing in piping.

Structure: The basic body, including floor deck material and installation, load-bearing external panels, structural components, axle mounting provisions and suspension beams and attachment points.

Subcontractor: Any manufacturer, company or Agency providing units, components or subassemblies for inclusion in the bus that are installed by a Subcontractor. Subcontractor items shall require qualification by type and acceptance tests in accordance with requirements defined in the Quality Assurance section.

NOTE: In the course of this Contract, the Authority may interchangeably use the words subcontractor, supplier, sub-supplier, vendor, as synonyms, all the aforementioned being under contract to the Contractor.

Superior Warranty: A warranty still in effect after all contractually required warranties have expired. The remaining warranty is administered directly between the sub-supplier and the Agency.

Supplier: Any manufacturer, company or Agency providing units, components, or subassemblies for inclusion in the bus that are installed by the Contractor. Supplier items shall require qualification by type and acceptance tests in accordance with requirements defined in the Quality Assurance section.

Systems Integration: A process that iteratively combines implemented system elements and subsystems to form a complete system configuration that functionally works together as expected and does not create unsafe conditions.

Tamperproof: Fasteners are designated as tamperproof when they are selected so that they cannot be easily loosened by hand or with common tools such as a flat blade or cross-recessed head screwdriver or pliers. Tamperproof Fasteners shall be tamper-resistant Torx type.

Tight (used as a suffix): Apparatus is designated as "watertight," "dust-tight," etc., when so constructed that the enclosing case shall exclude the specified material(s).

Usable Capacity: The amount of electrical energy, expressed in kWh, in a fully charged ESS available during normal vehicle use. It does not include the electrical energy of the ESS that is not accessible due to battery protection and load shed programming.

Vehicle: Also bus

Warrantable End of Life: A measure of battery degradation determined as the point at which the batteries can no longer provide the energy or power required to meet the design operating profile and requirements of this technical specification notably TS 8.5 . It is expressed as a percentage of remaining battery capacity as compared with gross capacity at the beginning of useful life. For purposes of this specification, WEOL shall be a measure of the useful and intended life of the energy storage device. WEOL shall be used as a condition for battery replacement and to potentially initiate warranty claims. Warrantable End of Life shall mean the same as End of Life.

Wheelchair: A mobility aid belonging to any class of three- or four-wheeled devices, usable indoors, designed for and used by individuals with mobility impairments, whether operated manually or powered. A "common wheelchair" is such a device that does not exceed 30 in. in width and 48 in. in length measured 2 in. above the ground and does not weigh more than 600 lbs when occupied.

Work: Any and all labor, supervision, services, materials, machinery, equipment, tools, supplies and facilities called for by the Contract and necessary to the completion thereof.

Zero-Emission Vehicle (ZEV): A vehicle that emits no tailpipe emissions from the onboard source of power.

The following are abbreviations used in this document:

ADB	Advanced Design Bus
AVL	Automated Vehicle Location
AVM	Automated Vehicle Monitoring
°F	Degrees Fahrenheit
°C	Degrees Celsius
BAFO	Best and Final Offer
BEB	Battery Electric Bus
CAD	Computer Aided Dispatch
CDR	Contract Deliverables Requirements
cfm	Cubic Feet Per Minute
DC	Direct Current
EMI	Electromagnetic Interference
ESS	Energy Storage System
FEA	Finite Element Analysis
FMEA	Failure Mode and Effects Analysis
F.O.B.	Freight on Board
fpm	Feet Per Minute
fpsps	Feet Per Second Per Second
FRP	Fiber Reinforced Plastic
GPS	Global Positioning System
GVWR	Gross Vehicle Weight, Rated
HCFC	Hydrochlorofluorocarbon
HP	Horsepower
HVAC	Heating Ventilation and Air Conditioning
Hz	Hertz
IP	IP Code or International Protection Code
ITS	Intelligent Transportation System
kHz	Kilohertz
LED	Light Emitting Diode
lbs	Pounds
mA	milli-Ampere
MBTA	Massachusetts Bay Transportation Authority
MHz	Megahertz
mph	Miles Per Hour

mphps	Miles Per Hour Per Second
MMBF	Mean Mileage Between Failures
MTTR	Mean Time To Repair
NTP	Notice To Proceed
OEM	Original Equipment Manufacturer
OPM	Original Part Manufacturer
PA	Passenger Announcements
PLC	Programmable Logic Controller
psi	Pounds Per Square Inch
psig	Pounds Per Square Inch, Gauge
RFI	Radio Frequency Interference
rpm	Revolutions Per Minute
SHGC	Solar Heat Gain Coefficient
SLW	Seated Load Weight
ULSD	Ultra Low Sulfur Diesel
VMS	Vehicle Messaging System

The following is a list of acronyms, standards and codes used in this document and its Attachments. All standards and codes that are specified in these Technical Specifications are the latest revisions unless otherwise noted. The latest revision in effect for each standard at the time of Notice to Proceed (NTP) shall be used in conjunction with the Technical Specifications.

ADA	Americans with Disabilities Act
ANSI	American National Standards Institute
APA	American Plywood Association
APTA	American Public Transit Association
ARB	Air Resources Board (also known as CARB)
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASCII	American Standard Code for Information Interchange
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association of America
AWG	American Wire Gauge
AWS	American Welding Society
BMCS	Bureau of Motor Carrier Safety
CFR	Code of Federal Regulations
CISPR	Comité International Spécial des Perturbations Radioélectrique
DOT	United States Department of Transportation
DPU	Massachusetts Department of Public Utilities
EIA	Electronic Industries Association

EPA	Environmental Protection Agency
FCC	Federal Communications Commission
FMCSR	Federal Motor Carrier Safety Regulations
FMVSS	Federal Motor Vehicle Safety Standards
FTA	Federal Transit Administration (formerly UMTA), an agency within the DOT
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Standards Organization
JIC	Joint Industrial Council
MIL	Military Specification
NEC	National Electrical Code
NEMA	National Electrical Manufacturers' Association
NFPA	National Fire Protection Association
NHTSA	National Highway Traffic Safety Administration
PCMCIA	Personal Computer Memory Card International Association
PTI	Thomas D. Larson Pennsylvania Transportation Institute
SAE	Society of Automotive Engineers
SPI	Society of the Plastics Industry
STURAA	Surface Transportation and Uniform Relocation Assistance Act
UL	Underwriters Laboratories Incorporated
USDOT	United States Department of Transportation

TS 3. Referenced Publications

The documents or portions thereof referenced within this specification shall be considered part of the requirements of the specification. The edition indicated for each referenced document is the current edition, as of the date of the issuance of this specification. The Contractor is responsible for complying with current referenced documents.

Any inconsistency in compliance with this Technical Specification and its referenced documents shall be resolved by giving precedence in the following order:

1. Federal requirements (Title 49, FMVSS, etc.)
2. State requirements (in Massachusetts, for example, it would be Massachusetts General Laws and Code of Massachusetts Regulations (CMR)
3. Local requirements
4. Referenced standards, practices, and codes (SAE, ASTM, UL, ISO, etc.)
5. Terms and Conditions
6. Technical content of this Technical Specification

TS 4. Design Review Process and Documentation Requirements

To ensure that the buses being procured under this contract are designed and built in compliance to this specification, a structured design review process and schedule is outlined below. In addition, a list of contractual deliverables are defined which lead to design definition, Pilot bus(es) design approvals, First Article Inspections, and the Baseline Design Configuration for all production buses. Any and all changes

from the Baseline Design Configuration shall require formal notification of the Authority for approval. Any changes made must be tracked in bus history books, and vehicles built prior to the cut in of the change shall require updates to ensure that they are in line with the new Baseline Design Configuration.

During the design review and approval process, drawing and data approvals shall be dispositioned as outlined in TABLE 1 Contract Deliverables Requirements .

All Contract Deliverable items that do not receive "Approved" status at the designated Project Design meetings, shall be resubmitted prior to the next Design Review meeting and achieve at a minimum "Conditionally Approved" status.

The Contractor shall provide all required Deliverables, status updates, or questions, two weeks in advance of each Project Design meeting to permit sufficient time for Authority review and to achieve required bus delivery schedule. At the Authority's discretion, failure to submit Deliverables in this manner may delay the First Article Inspection (FAI) date.

Contract Deliverables identified as being supplied in a "Hardcopy" format, shall also be provided electronically via email or other method approved by the Authority.

Contract Deliverables identified as being supplied in an "Electronic Media" format shall be provided on a secure USB flash drive (Kingston Data Traveler Vault Privacy 3.0 or latest revision secure flash drive) or other permanent media approved by the Authority.

All Contract Deliverables must be provided in a file format approved by the Authority, such as Adobe PDF.

TS 4.1 Design Review Schedule

The design review process shall include the following: a Kickoff meeting (within 2 weeks following NTP), Pre-Production meeting (approximately within 4 weeks following NTP), an Initial Design Review meeting (approximately within 8 weeks following NTP), Intermediate Design Review meeting(s) (approximately within 12 weeks following NTP), with additional meetings to be held as required by the Contractor and/or Authority), and a Final Design Review meeting (approximately within 16 weeks following NTP).

Additionally, weekly project design review teleconference and/or web-based meetings (duration of approximately an hour) shall be arranged between the Contractor, Sub-suppliers, and Authority representatives as needed throughout the design review process to continue design discussions and provide project/deliverables updates.

The Contractor shall provide sufficient information through this process to explain how the Battery Electric Bus meets the specification requirements within and satisfies the Contract Deliverables Requirements (CDRs).

TS 4.2 Contract Deliverables Requirements (CDR) List

The listings of CDRs provided in TABLE 1 are prepared as representations of the deliverables required throughout the specification. However, this listing is solely for reference and does not claim to have all CDRs as defined by the contract documentation herein.

TS 4.3 Kickoff Meeting

Within two (2) weeks following the NTP a project kickoff meeting at a time and location to be determined by the Authority shall be held. The prime focus of this meeting shall be a joint line-by-line review of the Technical Specification, TS Attachments, and Contractor's RFP Attachment 4 *Vehicle Technical Data Sheet*, conducted as a means to provide clarification and identify discrepancies that shall be addressed as part of the Design Review process. Additionally the Contractor shall present the proposed

Project Schedule **(CDR 1),** Production Schedule **(CDR 2)**, Quality Assurance Program Plan **(CDR 3)**, and Contractor's proposed CDR Schedule **(CDR 4)**.

The Contractor shall provide their proposed Project Schedule and Production schedule in line with the requirements of RFP Section 4.

The Contractor's Project Schedule **(CDR 1)** at a minimum shall include their proposed timeline for providing all deliverables to include delivery of all items in **Table 2**.

The Contractor's Production Schedule **(CDR 2)** at a minimum shall include their proposed line entry and exit dates, and delivery dates. The Contractor shall provide a map of their facility identifying locations of all stages of production and QA inspection stations/hold points, and shall include time spent by a bus in each stage.

The Contractor shall provide their Quality Assurance Program Plan **(CDR 3)** that meets all the requirements of the Technical Specification and RFP Section 10. The Contractor's Quality Plan shall be reviewed during the Pre-Production meeting.

The Contractor bears the responsibility for submitting a complete and comprehensive CDR schedule in accordance with (**CDR 4)** for the Authority's review and approval at the Kickoff Meeting.

The schedule shall include the following:

1. Item Number
2. Deliverable Description
3. Agency Action (review or approval)
4. Contract Specification Reference
5. Required Submittal Date
6. Actual Submittal Date
7. Format of Submittal
8. Quantity to be Submitted
9. Current Status and Any Other Pertinent Information.

Following schedule approval, the Contractor shall continue to provide progress updates as necessary. The Authority reserves the right to increase / decrease CDRs as required during the course of the Contract.

TABLE 1
Contract Deliverables Requirements

CDR Number and Deliverable		Agency Action	Reference Section	Due Date	Format	Quantity Due
Kickoff Meeting, TS 4.3 (within 2-weeks following NTP) *All Deliverables required for this meeting and/or questions shall be submitted to the Authority no later than 2-weeks prior to the Kickoff meeting.*						
1.	Project Schedule	Review	TS 4.3 RFP 4	Project Kickoff Meeting	Hardcopy and Electronic media	1
2.	Production Schedule	Review	TS 4.3 RFP 4	Project Kickoff Meeting, updated as necessary	Hardcopy and Electronic media	1
3.	Copy of Manufacturers' formal Quality Assurance Program	Review	TS 4.3 RFP 10	Project Kickoff Meeting	Hardcopy and Electronic media	1
4.	CDR Schedule	Review	TS 4.3	Project Kickoff Meeting	Hardcopy and Electronic media	1
Pre-Production Meeting, TS 4.3 (within 4-weeks following NTP) *Review of all open items not approved during previous meetings. All Deliverables required for this meeting, re-submitted items, status updates, and/or questions shall be submitted to the Authority no later than 2-weeks prior to the Pre-Production meeting.*						
5.	Preliminary Copy of the Bus History Book	Review	RFP 10.20	Pre-Production Meeting	Hardcopy and Electronic Media	1
6.	Battery Electric Bus and ESS Theory of Operations, BEB Energy Economy Optimization Test Plan, Load Shed Strategy, Regenerative Braking, Route Profile Analysis, Safe Minimum Sound Level, Post Delivery Performance Monitoring	Review	TS 4.12 TS 4.13 TS 8 TS 8.2 TS 8.8 TS 29.6	Pre-Production Meeting	Hardcopy and Electronic Media	5
7.	Safety Plan and Protocols Environmental Analysis of Anti-microbial Finishes/Coating ESS FMEA and Quantitative	Review	TS 1.2 TS 1.1 RFP 4.6 TS 8.6	Pre-Production Meeting	Hardcopy and Electronic media	5

TABLE 1
Contract Deliverables Requirements

CDR Number and Deliverable		Agency Action	Reference Section	Due Date	Format	Quantity Due
	Risk Assessment		RFP 10.15 TS 69.5			
8.	FMVSS Certifications	Review	TS 1.1 RFP 11.24.12(B,2,c)	Initially submitted with Proposal and reviewed at the Pre-Production Meeting	Certificates	1
9.	Altoona (PTI) Test Report	Review	TS 1.1 TS 7 TS 13.1 TS 13.2	Initially submitted with Proposal and reviewed at the Pre-Production Meeting	Hardcopy and Electronic media	1
10.	Design FMEA Report Review and Crashworthiness FEA Shaker Table Test report	Review	TS 13.2 TS 16 TS 29.7TS 29.6 TS 30.1	Pre-Production Meeting	Hardcopy and Electronic media	1
11.	Three Alternative Paint Scheme Drawing Proposals and Paint Test Procedures	Approval	TS 60.1 TS Attachment 1	Pre-Production Meeting	Hardcopy and Electronic media	1
12.	Three Alternative Driver Barrier or Bulkhead Options, and Driver's Protection System	Approval	TS 64.1 TS 64.2	Pre-Production Meeting	Hardcopy and Electronic media	1
13.	Three Alternative Passenger Seating Arrangements Flooring Farebox Platform and Retrofit Kit Interior Wall Covering Configuration and Color	Approval	TS 22.3 TS 64 TS 64.9 TS 68	Pre-Production Meeting	Hardcopy and Electronic media	1
14.	Destination Sign	Approval	TS 72	Pre-Production Meeting	Hardcopy and Electronic media	1

TABLE 1
Contract Deliverables Requirements

CDR Number and Deliverable		Agency Action	Reference Section	Due Date	Format	Quantity Due
			TS Attachment 4 (Section E)			
15.	Weight Control Strategy	Review	TS 5.1	Pre-Production Meeting	Hardcopy and Electronic media	1
16.	Corrosion Control Plan	Review	TS 17.1	Pre-Production Meeting	Hardcopy and Electronic media	1
17.	General Electrical Requirements, and Low Voltage Battery and Charging System	Review	TS 34	Pre-Production Meeting	Hardcopy and Electronic media	1
Initial Design Review Meeting, TS 4.5 (within 8-weeks following NTP) *Review of all open items not approved during previous meetings. All Deliverables required for this meeting, re-submitted items, status updates, and/or questions shall be submitted to the Authority no later than 2-weeks prior to the Initial Design Review meeting.*						
18.	Pilot Bus Program Plan	Review	TS 4.11	Submitted 2-weeks prior to the Initial Design Review Meeting	Hardcopy and Electronic media	1
19.	Design Review Approvals	Approval	TS 4.10 TS 31.6	Submitted 2-weeks prior to the Initial Design Review Meeting	Hardcopy and Electronic	1
20.	Pilot Bus Design Qualification Test Plan	Review	TS 1.2 TS 9 TS 13.2 TS 44 TS Attachment 2 (C and D)	Submitted 2-weeks prior to the Initial Design Review Meeting	Hardcopy and Electronic media	1
21.	Towing Procedures	Review	TS 18	Submitted 2-weeks	Hardcopy and	1

TABLE 1
Contract Deliverables Requirements

CDR Number and Deliverable		Agency Action	Reference Section	Due Date	Format	Quantity Due
	Towing/lifting adapters			prior to the Initial Design Review Meeting (Delivery of 12 adapters due with Pilot bus)	Electronic media	
22.	Test Program Plan	Approval	TS 1.1 TS 77 RFP 10.11 TS Attachment 2	Submitted 2-weeks prior to the Initial Design Review Meeting	Hardcopy and Electronic media	1
23.	Communication Systems Integration Plan including Camera Surveillance System	Approval	TS 76 TS Attachment 3 TS Attachment 4 TS Attachment 6	Submitted 2-weeks prior to the Initial Design Review Meeting	Hardcopy and Electronic media	1
24.	Critical Torque Identification and Verification Strategy	Approval	TS 5.2.6	Submitted 2-weeks prior to the Initial Design Review Meeting	Hardcopy and Electronic media	1
Intermediate Design Review Meeting, TS 4.6 (within 12-weeks following NTP) *Review of all open items not approved during previous meetings. All Deliverables required for this meeting, re-submitted items, status updates, and/or questions shall be submitted to the Authority no later than 2-weeks prior to the Intermediate Design Review meeting.*						
25.	Software Configuration Control and Management Services Software Escrow Plan	Approval	TS 75.1.1 TS 75.2.6 TS 79 TS 80 RFP 10.21	Submitted 2-weeks prior to the Intermediate Design Review Meeting	Hardcopy and Electronic media	1
26.	Interior Features – Fire-Resistance Certificates (Docket 90-A Certifications)	Approval	TS 5.9 TS 5.9.1 TS 40.5 TS 64	Intermediate Design Review Meeting	Certificates	1

TABLE 1
Contract Deliverables Requirements

CDR Number and Deliverable		Agency Action	Reference Section	Due Date	Format	Quantity Due
			TS 69.5			
27.	Lubrication List	Approval	TS 5.2.4	Submitted 2-weeks prior to the Intermediate Design Review Meeting	Hardcopy and Electronic media	1
28.	Multiplexing Data Communications	Approval	TS 36 TS 75	Submitted 2-weeks prior to the Intermediate Design Review Meeting	Hardcopy and Electronic media	1
Final Design Review Meeting, TS 4.7 (within 16-weeks following NTP) *Review of all open items not approved during previous meetings. All Deliverables required for this meeting, re-submitted items, status updates, and/or questions shall be submitted to the Authority no later than 2-weeks prior to the Final Design Review meeting.*						
29.	Draft Manuals & Records	Review	TS 5.6.1 TS Attachment 3 TS Attachment 4 TS Attachment 6 RFP 10.19	Submitted 2-weeks prior to the Final Design Review Meeting	Hardcopy and Electronic media	Various
30.	Training Plan & Schedule	Approval	TS 5.6 TS 5.6.7 TS Attachment 3 TS Attachment 4	Submitted 2-weeks prior to the Final Design Review Meeting	Hardcopy and Electronic media	1
31.	List of Recommended Consumable Spare Parts	Approval	TS 5.6.9	Submitted 2-weeks prior to the Final Design Review Meeting	Hardcopy and Electronic media	1
32.	Renewal Parts Inventory List & Parts Number Index	Approval	TS 5.6.8 TS 5.4 TS Attachment 3	Submitted 2-weeks prior to the Final Design Review Meeting	Hardcopy and Electronic media	1

TABLE 1
Contract Deliverables Requirements

CDR Number and Deliverable		Agency Action	Reference Section	Due Date	Format	Quantity Due
33.	Maintenance Review including recommended intervals / requirements Hoisting and Jacking Procedures	Review	TS 5.4 TS 19 TS 20	Submitted 2-weeks prior to the Final Design Review Meeting	Hardcopy and Electronic media	1
34.	ESS and Propulsion System Specific Maintenance Requirements	Review	TS 5.4 TS 8.3	Submitted 2-weeks prior to the Final Design Review Meeting	Hardcopy and Electronic Media	5
35.	Special Tools & Test Equipment	Review	TS 5.4 TS 5.6.3 TS 8.3 TS 8.5 TS Attachment 3 TS Attachment 5	Submitted 2-weeks prior to the Final Design Review Meeting	Hardcopy and Electronic Media	1
36.	Capital Spares List	Review	TS 22.3 RFP 5.9 (B)	Submitted 2-weeks prior to the Final Design Review Meeting	Hardcopy and Electronic Media	1
First Article Inspection (FAI) Meeting (upon completion of Pilot Bus) *All open items not approved during previous meetings, re-submitted items, status updates, and/or questions shall be submitted to the Authority no later than 2-weeks prior to the First Article Inspection meeting.*						
37.	First Article Acceptance Inspections (FAI)	Approval	TS 4.8 TS 5.2.5 RFP TS Attachment 2 Section (E)	Prior to delivery of Pilot Bus	Hardcopy	1

TABLE 1
Contract Deliverables Requirements

CDR Number and Deliverable		Agency Action	Reference Section	Due Date	Format	Quantity Due
38.	Sub-supplier Installation / Application Approvals	Approval	TS 4.10 TS 5 TS Attachment 2 Sections (C) and (E),	First Article Inspection	Certificates	1
39.	Interim Manuals (including electrical prints, pneumatic and hydraulic diagrams)	Review	TS 5.6.1	First Article Inspection	Hardcopy and Electronic media	Refer to TS 5.6.1
40.	Bus History Book	Approval	RFP 10.20	First Article Inspection	Hardcopy and Electronic media	1 per bus
41.	Resolution of issues "subject to Authority approval"	Approval	TS 4.8 TS 4.10.1	First Article Inspection	Hardcopy	1
Additional Contract Deliverables						
42.	Manuals & Records	Approval	TS 5.6.1	Refer to TS 5.6.1 for various delivery dates and quantities	Hardcopy and Electronic media	Refer to TS 5.6.1
43.	Operators Training	Approval	TS 5.6.2	Refer to TS 5.6.2 for various deliverable requirements		Refer to TS 5.6.2
44.	Maintenance Training	Approval	TS 5.6.3 TS 5.6.7	Refer to TS 5.6.3 and TS 5.6.7 for various deliverable requirements		Refer to TS 5.6.3 and TS 5.6.7
45.	Training Aids	Approval	TS 5.6.4 RFP 5.10	Prior to commencement of training programs	Parts & Equipment	
46.	Overhaul Shop Training	Approval	TS 5.6.5	Refer to TS 5.6.5 for various deliverable requirements		Refer to TS 5.6.5
47.	First Responder Training	Approval	TS 5.6.6	Refer to TS 5.6.6 for		Refer to TS

TABLE 1
Contract Deliverables Requirements

CDR Number and Deliverable		Agency Action	Reference Section	Due Date	Format	Quantity Due
				deliverable requirements		5.6.6
48.	Current Parts Pricing	Approval	TS 5.6.8	As part of FAI	Electronic media	4
49.	Materials Management Seminar	Approval	TS 5.6.8	Refer to TS 5.6.8TS 5.6.8 for various deliverable requirements		Refer to TS 5.6.8
50.	Contractor's Conformed As-Built Documentation and Specification / Final Vehicle Configuration	Approval	TS 4.14 RFP 4.7	Within 60 days after final bus delivery	Hardcopy and Electronic media	5
51.	As Built Drawings & Schematics	Approval	TS 4.14 RFP 4.6 (C)	Within 60 days after final bus delivery	Hardcopy and Electronic media	5

TS 4.4 Pre-Production Meeting

Pre-Production meetings may be held at the Contractor's manufacturing location, Authority locations in the Boston MA. area, or by remote/teleconference, with locations chosen at the discretion of the Authority. This series of meetings to be held within four weeks following NTP shall review schedules and items discussed during the Kick-off meeting, a review of deliverables **CDR 5** through **CDR 17** identified in TABLE 1 and shall lay the groundwork for the bus configuration.

A major focus of the Pre-Production meetings shall be a review of the Contractor's Quality Assurance Program and processes provided at the Kickoff meeting **(**reference **CDR 3).** The Contractor shall be prepared to demonstrate the quality processes and systems which are defined in their Quality Assurance Program plan and how these processes satisfy the requirements noted in RFP Section 10. This meeting shall encompass an audit of the Contractor's ongoing quality assurance processes, procedures, and documentation. Detailed discussions shall be held regarding, but not limited to: the Contactor's immediate interface with the Authority's resident inspector; responsibilities and reporting channels of the Contractor's QA inspectors; employee certifications (i.e. welding, HVAC, emissions); in-process testing; calibration of tools/test equipment; water testing; inspection stations/hold points; pre-shipment testing; resolution of reoccurring quality assurance problems, Contractor's facility safety and operational restrictions/policies (RFP Section 10.15), etc.

In addition, the Contractor shall present for discussion any and all items critical to design, delivery, testing, acceptance, quality, and overall contractual performance.

As part of the Pre-Production meetings, the Contractor shall also provide the following,

1. Preliminary Bus History Book **(CDR 5)** as defined in RFP Section 10.20, for the Authority's review with the final draft due for the Authority's approval as part of the Pilot Bus FAI.
2. Battery Electric Bus and ESS Theory of Operation, BEB Energy Economy Optimization and Test Plan, Load Shed Strategy, Regenerative Braking, Route Profile Analysis, Safe Minimum Sound Level, and Post Delivery Performance Monitoring **(CDR 6)** to include how the Contractor's proposed configuration meets the requirements of TS 4.12, TS 4.13 , TS 8 , TS 8.2 , TS 8.8 , TS 29.6
3. Safety Plan and Protocols, Environmental Analysis of Anti-microbial Finishes and Coatings, ESS FMEA and ESS Quantitative Risk Assessment **(CDR 7)** per the requirements of TS 1.1 , TS 1.2 ,TS 8.6 , TS 69.5 , RFP 4.6, and RFP 10.15 for review
4. FMVSS Certifications **(CDR 8)** per TS 1.1, and RFP 11.24.12(B, 2, c), for review
5. Altoona Test Report and scoring **(CDR 9)** shall be reviewed with an emphasis on Performance, Durability and Bus Structure as per TS 1.1 , TS 7 , TS 13.1 , TS 13.2
6. Design FMEA Report of Structure, Brake System (TS 29.7), and Door Interlock systems (TS 30.1). The Structure FMEA report shall include a full FEA report per TS 13.2 and Crashworthiness FEA per TS 16. A Structural Validation shaker table test report (TS 13.2) shall be provided **(CDR 10)**
7. Three Alternative Paint Scheme Drawing Proposals and Paint Test Procedures **(CDR 11)** per the requirements of TS Attachment 1 and TS 60.1 for review and approval consideration
8. Three Alternative Driver Barrier or Bulkhead Options, and the Driver's Protection System **(CDR 12)** per the requirements of TS 64.1 and TS 64.2 for review and approval consideration
9. Three Alternative Passenger Seating Arrangements per the requirements of TS 68 for review and approval consideration, Interior wall covering configuration and color per TS 64 and TS 64.9, and Farebox platform and kit TS 22.3 **(CDR 13)**

10. Destination Sign (**CDR 14)** per the requirements of TS Attachment 4 (Section E) and TS 72
11. Weight Control Strategy **(CDR 15)** per the requirements of TS 5.1 to include weight benefit analysis for major components such as ESS type and size options and seating configuration
12. Corrosion Control Plan **(CDR 16)** defining the recommended Authority tasks required to maintain all structural and corrosion related warranties per TS 17.1
13. General Electrical Requirements and Low Voltage Battery and Charging System **(CDR 17)** to include documentation of how the proposed low voltage battery and charging configuration meets all requirements per TS 34

TS 4.5 Initial Design Review Meeting

The Initial Design Review meeting shall be held at a location of the Authority's choosing whether in person or video conference within eight weeks following NTP. The objective of the Initial Design Review meeting shall be for the Contractor to present the design details of the bus for the Authority's review and approval and shall resolve design issues that require the Authority prior approval. Those requirements that cannot be resolved shall be deferred to the design review process for resolution.

As part of the Initial Design Review meeting a review of all open items not approved during Pre-Production meetings shall occur. New or re-submitted items shall be submitted to the Authority no later than 2-weeks prior to the Initial Design Review meeting.

The Contractor shall also provide the following CDR two weeks prior to the Initial Design Review meeting, for review during the meeting,

1. Pilot Bus Program Plan **(CDR 18)** detailing schedule, procedures, and tests in development/construction of the Pilot(es) bus from inception through FAI and Pilot Bus testing at the Authority. (TS 4.11) and (TS Attachment 2)
2. Design Review Approvals **(CDR 19)** which require the Contractor to submit all items (including sub-supplier sign offs) in TS 4.10 (**Table 2**) and Air System Analysis and Component Manufacturers Application Signoff in TS 31.6 ,for review and approval consideration
3. Pilot Bus Design Qualification Test Plan **(CDR 20)** to include proof of concept tests and Pilot Bus test plan for the tests required in TS Attachment 2 Sections (C) and (D) also TS 1.2, TS 9, TS 13.2, TS 44
4. Towing Procedures review, and Towing and Lifting adapter **(CDR 21)** design review and compliance with TS 18 with delivery of material to coincide with delivery of the first Pilot Bus (12 sets in total)
5. Test Program Plan **(CDR 22)** per the requirements of TS 1.1, TS 77, TS Attachment 2 and RFP Section 10.11
6. Communications Integration Plan including Camera Surveillance System **(CDR 23)** as required in TS 76 ,TS Attachment 3 , TS Attachment 4, and TS Attachment 6
7. Critical Torque Identification and Verification Strategy **(CDR 24)** to include a list of all "critical" torque locations and values as well as fastener torque this is recorded through computerized torque tools (TS 5.2.6)

In addition to the above items, the Contractor shall be prepared to present any and all items critical to design, delivery, testing, acceptance, and overall contractual performance that were not resolved at the Pre-Production meeting.

TS 4.6 Intermediate Design Review Meeting(s)

The objective of the Intermediate Design Review meeting(s) shall be for the Contractor to gain Authority approval for all those items not approved during the Pre-Production meeting and at the Initial Design Review meeting. During the Intermediate Design Review meeting(s), a detailed review of the CDR tracking schedule and Test Program Plan shall be conducted to identify any open issues or concerns with the documentation submitted. New submittals shall be presented by the Contractor at that time.

The Contractor shall also provide the following CDR (per TABLE 1) for review (and approval as required) during the Intermediate Design Review meeting,

1. Contractor's Software Configuration Control and Management Services Plan **(CDR 25)** per the requirement of TS 75.1.1, TS 75.2.6, TS 79 and RFP 10.4.
2. Software Escrow Plan **(CDR 25)** to include a list all OEM software comprising proprietary works ("Proprietary Software") for all major vehicle subsystems and vehicle drawings; the Contractor's escrow policies; Contractor's proposed Software Escrow Agreement; and the Contractor's procedures for providing technical assistance to the Authority (TS 80; RFP 10.21)
3. Interior Features – Fire Resistance Certificates (Docket 90-A Certifications) **(CDR 26)** shall be presented to the Authority for approval (TS 5.9, TS 5.9.1, TS 40.5, TS 64, TS 69.5)
4. Lubrication List **(CDR 27)** for approval (TS 5.2.4)
5. Multiplexing and Data Communications **(CDR 28)** per the requirements of TS 36 and TS 75

Intermediate Design Review meeting(s) shall be held at the Contractor's facility or a location determined by the Authority.

TS 4.7 Final Design Review Meeting

A final review of all the design drawings, required analysis, Authority Approvals and Contract Deliverables shall be conducted during the Final Design Review meeting. Items closed during earlier reviews need not be addressed again. All open items from previous meetings must be submitted to the Authority at least two weeks before the Final Design Review meeting. The objective of the Final Design Review meeting is to freeze the design of the Pilot Bus and to assure both the Authority and the Contractor that there is total agreement as to the configuration of the Pilot Bus.

The Contractor shall also provide the following CDR (per TABLE 1) for approval during the Final Design Review meeting,

1. Draft Manuals and Records **(CDR 29)** per TS 5.6.1, TS Attachment 3, TS Attachment 4, TS Attachment 6, and RFP 10.19 for review. A copy of the manuals for similar buses and equipment with notation to reflect required changes for the MBTA buses are acceptable for this submittal
2. Training Plan and Schedule **(CDR 30)** per TS 5.6, TS 5.6.7, TS Attachment 3, and TS Attachment 4, to include all maintenance, operator, backshop and additional, training schedule, curriculum, materials, for review and approval consideration
3. List of Recommended Consumable Spare Parts **(CDR 31)** to include OPM part numbers, per TS 5.6.9TS 5.6.9
4. Renewal Parts Inventory List and Parts Number Index **(CDR 32)** to include OPM part numbers, per TS 5.4, TS 5.6.8TS 5.6.8and TS Attachment 3
5. Maintenance Practices Review and Hoisting and Jacking Procedures **(CDR 33)** to include a maintenance review including recommended preventative maintenance schedule, other maintenance requirements, mileage based and time based maintenance, and hoisting procedures, for review TS 5.4, TS 19, and TS 20

6. ESS and Propulsion System Specific Maintenance Requirements **(CDR 34)** to include detailed information on system maintenance intervals and practices (TS 5.4 and TS 8.3)
7. Special Tools and Test Equipment **(CDR 35)** including a full list and delivery schedules of all Special Tools and Equipment per TS 5.4, TS 5.6.3, TS 8.3, TS 8.5, TS Attachment 3 and TS Attachment 5
8. Capital Spares list **(CDR 36)** including a full updated list of recommended Capital Spares materials and delivery schedule for the Authority review (TS 22.3 and RFP 5.9 (B))

Final Design Review meeting(s) shall be held at the Contractor's facility or a location determined by the Authority.

TS 4.8 First Article Inspection CDR

The Authority's project team shall conduct the FAI on the entire Pilot bus(es). This shall be the first opportunity the Authority shall have to see all components / sub-assemblies installed and a serviceability review can be conducted. The FAI shall be conducted at the Contractor's facility or at a location of the Authority's choosing.

1. First Article Inspection (FAI) **(CDR 37)** shall be conducted on the Pilot bus(es) to establish the quality level of workmanship that shall be maintained throughout production (TS 4.8, TS 5.2.5, and TS Attachment 2 Section E)
2. Sub-Supplier Installation/Application Approvals **(CDR 38)** - Upon completion of final design reviews, at the Authority's discretion, first article inspections (FAI) for all major sub-suppliers may be conducted. The FAI location(s) shall be as appropriate for the item(s) being reviewed and approved by the Authority. Reference TS 4.10, TS 5, and TS Attachment 2 Sections (C) and (E), for specific FAI requirements
3. Interim Manuals **(CDR 39)** shall be provided for review per TS 5.6.1
4. Bus History Book **(CDR 40)** shall be provided for review and approval consideration (RFP 10.20)
5. Resolution of Issues "Subject to Authority Approval" **(CDR 41)** to be resolved with the FAI (TS 4.8 and TS 4.10.1)

TS 4.9 Additional Contract Deliverables

The Contractor shall provide training, manuals, training aids, drawings as identified below. CDR's shall not be considered complete and closed until the last deliverable in a CDR is provided to, and accepted by, the Authority.

1. Manuals and Records **(CDR 42)** per the delivery requirements identified in TS 5.6.1
2. Operator's Training **(CDR 43)** per the requirements of TS 5.6.2
3. Maintenance Training **(CDR 44)** per the requirements of TS 5.6.3 and TS 5.6.7
4. Training Aids **(CDR 45)** per the requirements of TS 5.6.4 and RFP 5.10
5. Overhaul Shop Training **(CDR 46)** per the requirements of TS 5.6.5
6. First Responder Training **(CDR 47)** per the requirements of TS 5.6.6TS 5.6.5
7. Current Parts Pricing **(CDR 48)** for Renewal Parts (TS 5.6.8) and Consumable Parts (TS 5.6.9) effective and provided on the FAI date (TS 5.6.8)
8. Materials Management Seminar **(CDR 49)** to familiarize material management personnel with bus components, parts number system etc. per TS 5.6.8

9. Contractor's Conformed As-Built Documentation and Specification / Final Vehicle Configuration **(CDR 50)** per requirements of TS 4.14 and RFP 4.7
10. As-Built Drawings and Schematics **(CDR 51)** per requirements of TS 4.14 and RFP 4.6 (C)

TS 4.10 Design Review Approvals

Table 2 provides a summary of specified areas which require Authority approval as part of the Design Review Process **(CDR 19)**. The Authority requires appropriate detailed support documentation / information for each item to demonstrate compliance with the specifications requirements. Examples of appropriate support documentation include detailed technical documentation, materials samples, test reports (See also TS Attachment 2), or other information as required.

Certain systems and installations also require that the system supplier approve the application / installation. These items are indicated are indicated in **Table 2** under "Sub-supplier Signoff Required" **(CDR 38).**

Table 2 is provided solely for the convenience of the Contractor and does not purport to be complete. Said listing remains subject to modification by the Authority during contract execution.

TABLE 2
Design Review Deliverables and Sub-Supplier Signoff Requirements

D	**1.**	Welding Procedures, Drawings of Critical Welds, and Welder Certifications	TS 5.2.5	
D	**2.**	Composite Flooring Specifications & Installation Procedures	TS 21.3	X
D	**3.**	Materials Samples (including paint chips)	TS 5.2.1	
D	**4.**	Paint Scheme, Procedures, and Quality Standards	TS Attachment 1	X
D	**5.**	Exterior LED Lighting	TS 62	
D	**6.**	Interior LED Lighting	TS 65	
D	**7.**	Signage and Decals: Listing, Specifications, and Locations	TS Attachment 1	X
D	**8.**	Windows including window layout and egress locations	TS 41	X
D	**9.**	Seating Layout and installation, including stanchions and mobility device/wheelchair securement provisions	TS 68	X
D	**10.**	Entrance and Exit Door Systems	TS 70	X
D	**11.**	Driver's area layout including all dash panels and driver controls, driver's seat, mirrors	TS 37 TS 38 TS 40	
D	**12.**	Component Thermal Management System(s)	TS 9	X
D	**13.**	HVAC, Auxiliary Heater, Passenger Compartment Air Treatment System	X TS 42 TS 43.1 TS 46	X
D	**14.**	Fire Suppression	TS 5.10	X
D	**15.**	Propulsion System	TS 8 TS 10	X

TABLE 2
Design Review Deliverables and Sub-Supplier Signoff Requirements

D	**16.**	Energy Storage System	TS 8	X
D	**17.**	Fuel System Design	TS 12	X
D	**18.**	Pneumatic System	TS 31	X
D	**19.**	Brake System	TS 29	
D	**20.**	Camera System including layout and views (refer to TS Attachment 3 Section 1.2 for additional deliverable dates and requirements)	TS 76.6 TS Attachment 3	X
D	**21.**	Communications System	TS Attachment 4	X
D	**22.**	Special Tools & Test Equipment	TS Attachment 5	X
D	**23.**	Mobile Radio System	TS Attachment 6	X
D	**24.**	Passenger Counters	TS 76.7	X
D	**25.**	Fare Collection Validation System	TS 66.1 TS Attachment 7	X
D	**26.**	Accessibility Provisions	TS 71	X
D	**27.**	Steering System and Front Axle	TS 26	X
D	**28.**	Drive Axle	TS 27	X
D	**29.**	Suspension	TS 24	X
D	**30.**	Accessories (including bicycle rack, passenger information systems	TS 73 TS 74 TS 78	X

TS 4.10.1 Approved Equal

Throughout this specification, specific products have been identified which are known to satisfy the Authority's requirements for service proven performance, durability, and overall value. In cases where a specific product is identified by name and/or part number, the Contractor may elect to submit service proven alternative products for the Authority's consideration. These submittals shall be known as "Requests for Approved Equal" and shall be formally submitted for the Authority's approval.

When submitting a Request for Approved Equal, the Contractor shall develop a line item compliance matrix which defines the "key characteristics" by which the Contractor can demonstrate that the alternative product being proposed is equivalent or better than the product originally specified.

The Contractor shall provide appropriate supporting documentation (including drawings, a parts sample, materials specifications, product "cut sheets", test reports, standard warranty statement, and current transit bus fleet users with contact name / phone number / quantity in use) as required to demonstrate equivalence to the Authority's satisfaction.

Requests for Approved Equal shall be submitted as early in the Design Review Process as possible, so as to minimize disruptions to the overall process and to maximize time to evaluate / discuss the Request.

Resolution of Issues "Subject to Authority Approval" are to be resolved with the FAI **(CDR 41)**.

TS 4.10.2 Service Proven Bus

Service proven vehicle designs shall have appropriate Quality service history with documentation reflecting performance in previous applications. The Authority shall make all appropriate determinations in regard to acceptable service history.

All new systems / assemblies considered in this manner shall be submitted by the Contractor in line with the Request for Approved Equal Process (reference TS 4.10.1).

The Authority is amenable to take advantage of new technologies when practical and risks are low. The Contractor shall demonstrate the benefit of using any new technology being proposed and provided assurances that the Authority shall not end up with a problematic design. The Authority requires that all buses, bus systems, and component designs shall be service proven.

TS 4.11 Pilot Bus Programs

Pilot Buses shall be provided and delivered to the Authority per the Delivery requirements of RFP 4.3. Pilot buses shall be used for testing and demonstration on the Authority's property for a two-month period. The Contractor shall provide a Field Service Engineer per the requirements of RFP Section 7.3. The objective of the Pilot Bus Program is to ensure that an acceptable design configuration and vehicle performance is achieved and to lessen the probability of costly and inconvenient retrofits. At the end of the two-month test period, the preferences of the MBTA Operations and Maintenance Departments as well as any known problems and required modifications shall be identified and conveyed to the Contractor. The design configuration defined at that time shall become the basis for the production of buses 3 through the end of production under this Contract.

The Contractor shall submit for Authority approval a detailed Pilot Bus Program Plan at the Initial Design Review Meeting. Pilot Bus Testing shall be conducted in accordance with TS Attachment 2 Sections C and F. Because of scheduling constraints, the Contractor may, with the Authority’s approval, begin production of buses two (2) through the end of production upon successful completion of Pilot Bus Testing and Demonstration program and approval of Final Design and Baseline Design Configuration by the Authority.

The Authority reserves the right to conduct detailed First Article Inspections (FAI) on major subsystems including but not limited to propulsion, axle, energy storage, and HVAC systems as required. Major sub-system suppliers are required to provide detailed testing and installation procedures in addition to providing an on-site representative for review of their installations on the Pilot Buses.

TS 4.12 Post Delivery Evaluation of Battery Electric Buses and Energy Economy Optimization Test Program

The Contractor shall develop an Energy Economy Optimization test program plan that shall commence upon arrival of the Pilot Buses.

Both Pilot Buses and five (5) serial production buses shall be evaluated by the Authority upon delivery in Boston with the assistance of the Contractor and the propulsion and ESS system supplier. The Contractor shall instrument and monitor these vehicles in passenger service. Each vehicle shall be monitored for a minimum period of 12 months.

Data shall be collected and evaluated by the Contractor with the goal of optimizing energy economy.

At the end of each 3 month period, the Contractor shall prepare an interim report for the Authority, which shall include a summary of findings to date and any proposed modifications to optimize desired performance.

The Contractor shall be responsible for all configuration changes needed to address any deficiencies identified which result in the buses not meeting Technical Specification performance requirements.

At the end of the testing period for the last of these vehicles, the Contractor shall prepare a report detailing the findings of the evaluation. The report shall be provided to the Authority no later than one month from the conclusion of the testing period. Performance increases above the base Technical Specification requirements shall be reviewed by the Authority on a case by case basis for potential changes to configuration.

All raw unencrypted data collected during this test period shall be shared with the Authority.

The Contractor shall provide a detailed test plan for Authority review and approval as part of the Design Review process **(CDR 6).**

TS 4.13 Post Delivery Performance Monitoring

Both Pilot Buses and five (5) serial production buses shall be outfitted with data loggers designed to monitor bus performance, provide fault detection, monitor major system components, monitor ESS loads and degradation, and retain timestamped data. The system must be able to monitor major system component and ESS cycling and operating conditions and be capable of providing unencrypted data in a raw format useful for component life cycle analysis.

The Contractor and propulsion and ESS system supplier shall instrument and monitor these vehicles in passenger service and provide analysis assistance and reports as requested by the Authority. Each vehicle shall be monitored for a minimum period of 14 years. **(CDR 6)**

TS 4.14 As-Built and Contractor Drawings and Documentation

As-Built drawings and documentation shall be provided for use by the Authority for internal training, maintenance, and repair purposes as well as to fully document the final design configuration of the bus fleet. All As-Built specifications, drawings, drawings required for structural repair, schematics, and general system layouts shall be provided. This documentation shall describe all key components and systems of each bus and reflect the latest design configuration and all revisions. Additional as-built documentation requirements are identified in Technical Specification Attachments and RFP 1F-22. This documentation shall be delivered no later than 60 days after the delivery of the final production bus. Subsequent changes to the vehicle configuration shall be documented and "slide in" updates and shall be provided by the Contractor **(CDR 50) (CDR 51).**

Documentation shall be printed hard copy and electronic. The Contractor shall provide electronic documentation on separate secure USB flash drives (Kingston Data Traveler Vault Privacy 3.0 or latest revision secure flash drive) .

TS 5. Overall Requirements

The Contractor shall ensure that the application and installation of major bus subcomponents and systems are compliant with all such subcomponent vendors' requirements and recommendations. Components used in the vehicle shall be of heavy-duty design and service proven in transit service. (refer to TS 4.10)

TS 5.1 Weight and Capacity

It shall be a design goal to construct each bus as light in weight as possible without degradation of safety, appearance, comfort, traction, or performance. Curb weight shall not exceed 30,500 lbs. and shall be adjusted for the weight of equipment supplied under changes ordered.

The bus shall be designed for a gross load calculated as 200 lbs. for the driver plus 600 lbs for each wheelchair position plus 150 lbs. for each designed passenger seating position and for each 1.5 sq. ft. of free floor space. Base order buses shall accommodate no less than 36 seated passengers. Buses with the streetside boarding configuration option shall accommodate no less than 31 seated passengers.

All equipment shall be arranged so that its weight is distributed to equalize tire loading not in excess of tire rating and maximize adhesion braking and propulsion. The tire loading on opposite sides of an axle shall be within 5% of each other at gross load.

The Contractor shall provide the Authority a Weight Control Strategy **(CDR 14)** during the Pre-Production meeting and provide updates throughout all phases of bus design development. The Weight Control Strategy shall also include an analysis of each Alternative Passenger Seating arrangement **(CDR 13)** and the effects on axle loads from seated and standing passengers, and weight/benefit analysis for major components such as ESS type and size options.

Buses at gross load shall not exceed the tire factor limits, axle ratings, brake test criteria, or structural design criteria.

The vehicle shall be designed to carry the gross weight with a GVW that shall not exceed the bus GVWR.

The Contractor shall provide documentation of the actual corner weighting of the Pilot Buses loaded to gross weight and distribution.

TS 5.2 Materials and Workmanship

TS 5.2.1 Materials

Upon request of the Authority the Contractor shall submit samples of materials for examination, tests, and concurrence. All samples requested in this Specification are to be sent to the Authority and shall be delivered F.O.B. destination as designated by the Authority.

All parts shall be new and in no case shall used, reconditioned, obsolete, or discontinued parts be used. Repairs or corrective actions to parts and components supplied under this Technical Specification shall be agreed upon in advance by the Authority. Any one part or unit used in the construction of these buses shall be an exact duplicate in manufacture, design, and construction of each of the base order buses. Optional buses may incorporate product improvements and upgrades with Authority approval.

To the maximum extent possible, sub-system design and parts commonality shall be consistent between fleets. Examples include but are not limited to HVAC; air compressor/air system; power steering; etc.

Fiber reinforced components shall not have sections that are fiber or matrix rich, or fiber or matrix poor. Plastic components shall not have resin rich, or resin poor sections.

All fiber and matrix materials used in the buses shall require prior approval by the Authority during the Design Review Process **(Table 2, D3).**

TS 5.2.2 Guards

Piping, pumps, wiring, control rods, and equipment located within the bus shall be adequately protected against damage or interference by, or hazard to, passengers or the operator. Inclusive of this requirement shall be fluids and other related materials.

When a shield or guard is placed around a unit requiring inspection and/or lubrication, the shield shall be so secured as to provide for easy access to the unit.

TS 5.2.3 Electromagnetic Protection

All electronic and electrical systems shall function properly without degradation from electromagnetic sources and without degrading the electromagnetic environment. All electronic and electrical systems shall not be susceptible to temporary or permanent malfunctions subject to electromagnetic sources, either transient or steady state in nature. Electromagnetic interference arising from sources such as transmitters or other equipment located either on-board or adjacent to the bus or from component parts of the bus's electrical power supply system shall not degrade the design life of the on-board electronic equipment.

TS 5.2.4 Fluids and Lubrication

A Fluids and Lubrication list shall be provided to the Authority indicating the Contractor's standard Fluids and Lubricants (Fluids). Current Authority Fluids and Lubricants are listed in **Table 3** below. If any fluids used on the bus are not compatible with Authority Fluids and Lubricants, the Contractor shall notify the Authority of any deviation, and such fluids shall require the concurrence of the Authority during the Intermediate Design Review meeting **(CDR 27).**

All elements of steering, suspension and drive systems requiring scheduled lubrication shall be provided with grease fittings conforming to SAE Standard J534. These fittings shall be located for ease of inspection and shall be accessible with a standard grease gun from a pit or with the bus on a hoist. When necessary, lubrication extension tubes shall be installed to ease access. Each element requiring lubrication shall have its own grease fitting with a relief path. The lubricant specified shall be standard for all elements on the bus serviced by standard fittings and shall be required no less than every 6000 miles.

TABLE 3
MBTA Fluids and Lubricants List as of 12.28.2020

Fluid	Description	Manufacturer
Synthetic Differential Oil	Delvac Synthetic Gear Oil (75W-90)	Mobil
Anti-Freeze/Coolant	Fleet Charge 50/50	Old World Industries
Power Steering Fluid	Kendal Versa – Tran ATF (Factory Fill – DEXRON III)	Conoco Phillips
Grease	Lithium Complex Hi Temp EP 2	
Wheelchair Ramp Hydraulic Oil	DEXRON III	
Entrance and Exit Door Baseplate Spherical Bearing	SAE 20	
Brake Treadle and Foot Valve Assembly	Barium Grease per BW-204-M	Bendix #246671
High Temperature Grease	NLGI Grade 2, drop point of at least 446 deg. F	

TS 5.2.5 General Conditions

All piping, pumps, tubing, cables, and wiring shall be properly routed and secured. All pass through holes for piping, tubing, cables, and wires shall be free of sharp and rough edges, protected by grommets, solid sleeve P-clamps or by other means, to prevent damage over the service life of the bus. Final approval of the protective provisions shall be provided by the Authority during the First Article Inspection.

All mounting of assemblies, subassemblies, and accessories, shall be mechanically isolated to minimize the transmission of vibration to the body structure.

All components and accessories located under the bus shall have provisions to protect the systems from road debris, ice, snow, and de-icing material, via a protective plate or other suitable means. All associated mounting brackets and covers shall be corrosion resistant per requirements of TS 17 and shall be configured to prevent the accumulation of road debris, de-icing material, ice, and snow.

All pipe fittings shall be of heavy-duty type and shall be designed to withstand the maximum pressure that could be generated under normal or overload conditions, within the air or fluid system of which they are a component.

All coolant and water lines routed through the interior of the bus shall be done in a method that prevents leaks into the interior of the bus. Provisions shall be made to retain all fluid leaks, which have the potential of entering the passenger and driver's area of the bus in a manner as approved by the Authority.

All line, hose, and pipe, interior diameter surfaces shall be free of all foreign substances to prevent a reduction of air/fluid flow and/or premature failure of connected components.

All burrs and sharp edges shall be dressed so as to prevent injury to passengers, operators, and maintenance personnel.

Wire ties shall be only used for bundling and shall be cut flush with no sharp edges.

P-clamps shall be used for routing bundles.

All clevises shall be removable and not welded to the rods.

The structure shall be assembled by bolting, riveting, welding, or adhesive bonding. All welding connections shall conform to AWS standards for quality and fitness for purpose. Welding procedures, welding materials, and qualifications of welding operators and inspectors shall be in accordance with AWS and ASTM standards. Appropriate European on (or) other international standards may be used if the Contractor demonstrates the equivalence of these standards to the Authority. Welds shall have a finished appearance where visible. For all welded connections, the contact surfaces shall be free of scale, grease, and paint. The Contractor shall supply design prints of all critical areas and joints of the structure to the Authority at the Initial Design Review meeting, for production inspection purposes **(Table 2, D1).**

Monocoque composite buses shall be of a chassis-less one piece design comprised of corrosion proof and non-electrically conductive materials manufactured with a uniform sandwich structure and contiguous fiber reinforced outer shell. The structure and shell shall be free from voids, neither resin rich nor resin poor, and impervious to stress related and cosmetic cracking and spidering throughout the 14 year or 500,000 mile service life of the bus.

All surfaces to which springs are attached shall be of a pattern as to prevent excessive grooving or wear of the parts.

All fasteners, mounts, and equipment shall be rated for the installed location and operating environment.

All bolted connections shall be designed to a minimum strength value of SAE Grade 5 or metric equivalent nuts and bolts using a minimum design margin of 1.5 based on proof load of the bolt. Bolts and nuts shall be SAE Grade 5 or better and marked according to SAE Standards J429 and J995 or metric equivalent. Any deviations from this standard shall require Authority approval during Design Review.

Bolt projections through nuts shall exceed 1-½ threads and shall not exceed thickness of a standard nut.

All sheet metal screws shall comply with ASTM and SAE recommendations relative to quality and installation. Phillips headed fasteners, self-tapping and sheet metal screws, rivets and rivnut-type fasteners shall not be used without prior approval of the Authority for each specific application.

Specific manufacturer's recommendations as to the adjustment and settings of components shall be provided to the Authority before delivery of the first bus. Items such as air spring heights, voltage regulator, air governor, and any other pertinent data shall be furnished to allow time to prepare service and inspection forms for initial bus inspection.

All air, hydraulic, and water lines and openings into equipment units shall be sealed, plugged, or adequately protected against entrance of contaminants until connected.

Mounting of major assemblies including traction motors/drive units, axles, power steering and suspension components shall be such that dismounting shall be easily carried out by conventional shop methods.

Drainage shall be provided in all body structure members. Enclosed structural cavities shall be vented to prevent condensate build up. Any enclosed structural cavities of steel members shall be treated with a rust-inhibiting coating**.**

TS 5.2.6 Fastener Torque

All fasteners used in the assembly of the complete bus shall be of an appropriate size and material for the rated loads and torqued to an appropriate level. The contractor shall identify a list of torques that are deemed to be critical for the safety and performance of the bus in service. These torques are to have an additional verification requirement to be either overseen by a supervisor or be recorded electronically by a computerized system.

The Contractor shall identify all critical torques and provide a listing of these fasteners, torque values, their location, and the contractors strategy for verification of the torque procedure for review of the authority **(CDR 24)**. The strategy for verification of critical torques performed by sub-suppliers or venders shall also be included in this submittal. The Authority reserves the right to conduct in-person site visits to sub-suppliers or vendors to verify conformance with the Contractor's stated policies/procedures as necessary.

TS 5.3 Design / Service Life

The minimum useful design/service life of the bus in transit service shall be at least fourteen (14) years or 500,000 miles in the Authority's operating environment, and shall be capable of operating at least 40,000 miles per year, including the 14^{th} year.

TS 5.4 Maintenance and Inspection

Scheduled maintenance tasks shall be related and shall be in accordance with the manufacturer's recommended preventative maintenance schedule (along with routine daily servicing). Scheduled maintenance activities shall be implemented in mileage-based intervals. If hour-based intervals are recommended by manufacturers, mileage-based conversions shall also be provided or means to monitor operational hours of systems shall be made available.

Test ports, as required, shall be provided for commonly checked functions on the bus, such as hydraulic, pneumatic, and thermal management systems.

The bus manufacturer shall give prime consideration to the routine problems of maintaining the vehicle. All bus components and systems, both mechanical and electrical, which shall require periodic physical work or inspection processes shall be installed so that a minimum amount of time is consumed in gaining access to critical repair areas. It shall not be necessary to disassemble portions of the bus structure and/or equipment such as seats, and flooring under seats, in order to gain access to these areas. Each bus shall be designed to facilitate the disassembly, reassembly, servicing, or maintenance, using tools and equipment that are normally available as standard commercial items. A maintenance review including recommended preventative maintenance schedule and other maintenance requirements shall be provided to the Authority as part of the Final Design Review meeting**(CDR 33)**.

Major mechanical system components (examples include the air compressor and electric power steering pump) shall have available "rebuild kits" to perform repairs without the requirement of changing out the entire unit.

Rebuild kit part numbers, list of components including OPM part numbering, and pricing shall be provided**. (CDR 32)**

The Contractor shall provide baseline life cycle replacement intervals (assuming OEM preventative maintenance procedures are followed) for major mechanical system components.

Requirements for the use of unique specialized tools shall be minimized. The body and structure of the bus as well as all components/systems shall be designed for ease of maintenance and repair. Individual

panels or other equipment that may be damaged in normal service shall be repairable or replaceable. Ease of repair shall be related to the vulnerability of the item to damage.

Contractor shall provide a list of all special tools and pricing required for maintaining this equipment.

> **NOTE:** Tools such as compartment door keys and other tools that are required for daily maintenance and inspections shall not be included in the special tool list and shall be furnished for each bus.

TS 5.5 Interchangeability

Unless otherwise agreed, all units and components procured under this Contract, whether provided by Suppliers or manufactured by the Contractor, shall be duplicates in design, manufacture and installation to ensure interchangeability among buses in each order group in this procurement. This interchangeability shall extend to the individual components as well as to their locations in the buses. These components shall include, but are not limited to, passenger window hardware, interior trim, lamps, lamp lenses and seat assemblies. Components with non-identical functions shall not be, or appear to be, interchangeable.

Any one component or unit used in the construction of these buses shall be an exact duplicate in design, manufacture, and assembly for each bus in each order group in this Contract. Contractor shall identify and secure approval for any changes in components or unit construction provided within a Contract.

In the event that the Contractor is unable to comply with the interchangeability requirement, the Contractor must notify the Authority and obtain the Authority's prior written approval, including any changes in pricing.

The Authority shall review proposed product changes on a case-by-case basis and shall have the right to require extended warranties to ensure that product changes perform at least as well as the originally supplied products.

TS 5.6 Training

The Contractor shall provide bus related training for Authority personnel to consist of six components:

1. Bus operation, which includes detecting and resolving in-service problems and emergencies that result in minimal delays.
2. Maintenance of systems, components, and assemblies, which includes inspections, lubrication, adjustments, repairs, and replacements normally performed on buses at the maintenance shop.
3. Overhaul or repair of components or assemblies normally performed at the Authority's overhaul shops.
4. 'Train the trainer' focused on First Responder activities and scenarios they may encounter and BEB familiarization
5. Familiarization with renewal parts
6. Virtual training modules in a digital format for continued Authority use

An outline, curriculum, and proposed materials, for each training program shall be submitted for Authority review and approval during the Final Design review meeting. **(CDR 30).**

1. The outline shall include the number of classroom and field instruction hours that the Contractor recommends for each system on the bus; the qualifications of the instructors; a list of training aids to be used and furnished; and a brief description of the scope of instruction to be provided
2. Refer to Operator Training (TS 5.6.2), Maintenance Training (TS 5.6.3), Overhaul Shop Training (TS 5.6.5), First Responder Training (TS 5.6.6), Additional Training per Attachment 3 and

Attachment 4 (TS 5.6.8), and Renewal Parts Inventory Seminar (TS 5.6.8) for additional and group specific Training requirements

3. A draft Renewal Parts Inventory Seminar (TS 5.6.8) presentation shall be provided by the Contractor during the Final Design Review meeting.

The Contractor and appropriate suppliers shall train Authority personnel on actual equipment whenever possible. The Contractor or suppliers shall be responsible for replacing any consumables and reestablishing the condition of any parts damaged as a direct result of training activities.

The Authority shall be responsible for providing classroom facilities.

TS 5.6.1 Manuals and Records

The Contractor shall provide complete and up-to-date manuals in both the electronic and hard copy formats to the Authority. The supplied manuals shall incorporate all equipment ordered on the buses covered by this procurement. In instances where copyright restrictions or other considerations prevent the Contractor from incorporating major components information into the bus parts and service manuals, separate manual sets as published by the subcomponent Supplier shall be provided to the Authority by the Contractor.

The Authority requires all required manuals, including all text and images within, to be available in an electronic media consistent with industry standards. The Authority's preferred format is HTML for deployment over its Windows NT-based Intranet. Appropriate navigation and frame structures shall be provided within these documents. It is encouraged that electronic linkages exist with the vendor to enhance customer support opportunities, including e-mail. Absent HTML protocol, manuals may be submitted in Adobe PDF or approved equal format on a secure USB flash drives (Kingston Data Traveler Vault Privacy 3.0 or latest revision secure flash drive). This PDF document shall allow footnotes, updates, comments, or clarifications to be made and saved to this same secure USB flash drive. Electronic files, regardless of format shall allow updates or changes at a later date by the Authority.

The Authority shall have the right to adjust manual quantities at any time up to and during the Final Design Review meeting.

The Authority's Materials Management Department is using PeopleSoft by Oracle as an interactive fleet parts management program. The Contractor shall be responsible for submitting to the Authority electronic files of all manuals formatted such that they are capable of being imported to this program.

Draft design of all Maintenance, Operator, Systems, and Material Management Department manuals and procedures shall be submitted two weeks before the Final Design Review meeting. Five copies of each shall be provided to the Authority on individual secure USB flash drives (Kingston Data Traveler Vault Privacy 3.0 or latest revision secure flash drive) or via a secure download. **(CDR 29)**

Five copies of the Maintenance, Operator, System, and Material Management Department documents (five of each; fifteen in total) shall be provided to the Authority by the Contractor at the Pilot Bus FAI for review on separate secure USB flash drives (Kingston Data Traveler Vault Privacy 3.0 or latest revision secure flash drive) for Authority review and approval consideration. **(CDR 37)**.

Ten (10) copies of complete updated *final* electronic Maintenance, Operator, Systems, and Material Management Department documents (ten of each; thirty in total), on separate secure USB flash drives (Kingston Data Traveler Vault Privacy 3.0 or latest revision secure flash drive) shall be provided to the MBTA prior to, or within, ten (10) days before Authority acceptance of the first production bus. The manuals shall be in a format approved by the Authority during the Design Review process. **(CDR 42)**

Additional Operator manual requirements **(CDR 42)** to coincide with TS 5.6.2 include,

1. Operator training shall be based on the Operator manual. To ensure the safety of maintenance personnel, operating personnel, and passengers, the Contractor shall provide Operator manuals which cover the following topics:
    a) Passenger service preparation
    b) Efficient operation of a Battery Electric Bus
    c) Start up and shut down procedures
    d) High voltage awareness
    e) Normal operating procedures
    f) Emergency operating procedures and any safety concerns
    g) Moving a bus with a problem (fault)
2. The Contractor shall include the proper operation of the mobility device/wheelchair ramp deployment systems and securement systems in the Operator manual.
3. The Contractor shall provide fifty (50) sets of printed Operator manuals one week before the initial Transportation Department pilot bus Operator training
4. The Contractor shall provide an additional five-hundred (500) printed hard copies of the Operator manual within thirty (30) days following delivery of the second pilot bus.

Additional Maintenance Manuals requirements **(CDR 42)** to coincide with TS 5.6.3 include,

1. Maintenance Manuals shall include all applicable "Special Listings", "and "Parts Manuals" for the buses furnished under the Specification **(CDR 37)**
2. Maintenance Manuals shall include ladder logic, propulsion system and ESS diagnostics, electrical prints, pneumatic diagrams, and hydraulic diagrams.
3. Within two weeks of delivery of the first production bus, the Contractor shall provide five (5) printed hard copies of all final Maintenance Manuals, complete with all applicable revisions included and inserted**.**
4. The Contractor shall furnish fifty (50) printed hard copies of Maintenance Training manuals prior to the second part of Maintenance Training (approximately one (1) month after the delivery of the first serial production bus) for each subject listed in TS 5.6.3.
    a) Five copies of the Maintenance Training manuals shall also be provided by the Contractor on separate secure USB flash drives (Kingston Data Traveler Vault Privacy 3.0 or latest revision secure flash drive). Each electronic copy of the Training manuals shall include a full set of the manuals listed in TS 5.6.3
    b) In lieu of special Training manuals, the Contractor may utilize the Running Repair and Service Manual, the Schedule Repair and Overhaul Manual and/or applicable Vendor Manuals for instructional purposes
        i. In the event the Contractor utilizes such Training manuals, they shall be in addition to other Maintenance Manual requirements

Additional Manual Requirements (**CDR 39**) include

1. Operation and Maintenance Manuals as required by TS Attachment 3 Mobile Closed Circuit Television System Section 1.2 (M)
2. Communications Equipment manuals per the requirements of TS Attachment 4

3. Mobil Radio per the requirements of TS Attachment 6

The Contractor shall be responsible for providing the Authority with all applicable revisions and updates to all manuals for a period of fifteen (15) years from the date the last production bus was accepted by the Authority.

At the end of the bumper-to bumper warranty period for the last serial production bus (RFP Section 9), the Contractor shall provide ten sets of all manuals in electronic format on secure USB flash drives and ten sets of printed hard copies to include all revisions and service bulletin information.

As revisions and updates occur, the Contractor shall provide five electronic copies and five printed copies, per the appropriate format requirements noted above, to the MBTA Vehicle Engineering department.

TS 5.6.2 Operator Training

Operator training shall be based on the Operator Manual as noted in TS 5.6.1 . The Contractor provided training shall include:

1. Passenger service preparation
2. Efficient operation of a Battery Electric Bus
3. Normal operating procedures
4. Emergency operating procedures and any safety concerns
5. Moving a bus with a problem (fault).

The Contractor shall include the proper operation of the mobility device/wheelchair ramp deployment systems and securement systems in the Operator Manual.

Within two weeks of the delivery of the first Pilot Bus, the Contractor shall instruct 2 groups of 10 representatives from the Transportation Department during separate 2-day training sessions. The training shall take place at the Maintenance Facility and as required, on-board a fully operational Pilot bus.

A one day, follow-up session shall be held for up to twenty (20) trainees. The follow-up shall take place approximately one month after the first ten serial production buses have been accepted for passenger service. The Contractor shall provide an agenda for Authority approval at least one (1) week prior to the training. **(CDR 30) (CDR 43).**

TS 5.6.3 Maintenance Training

As part of the maintenance-training program ten (10) complete sets of all special tools and test equipment, necessary to service and maintain each bus system, shall be provided prior to the delivery of the first Pilot Bus. Special tools are defined as those not readily available from hardware store or Snap-On. Example of standard tools are combination wrenches, screws drivers, hammers or tools that would normally be found in a mechanic toolbox. Example of special tools are temperature adapters, pressure probes, axle and brake OEM tools, laptops with all appropriate diagnostic software installed, training smart boards, etc…

The Contractor shall provide sufficient training for the Authority's personnel to permit satisfactory servicing and maintenance of the buses at the Authority's garages. The training shall include classroom and "hands-on" instruction. The "hands-on" instruction shall be given on an operational bus or on functioning mockup training aids and include an introduction to faults, troubleshooting and subsequent repair. Training shall include instruction of remote CAN diagnostic utilities.

Instructions and/or training on how to use these special tools and equipment shall be provided at the same time. Classroom instruction shall include not only the anatomy and functionality of the parts, but also the essentials of routine care including maintenance schedules, adjustments, limits, test frequency, inspection

frequency, troubleshooting, component and subcomponent diagnosis, removal, and replacement, high voltage safety, and a pre- and post-course test.

The Contractor shall assume that the Authority has no special tools for bus maintenance. At the completion of the training program the special tools, test equipment, and training aids used by the Contractor for training shall be turned over to the Authority in proper working order. At the conclusion of the classroom instructions, the Contractor shall furnish to the Authority a complete set of lesson plans including, but not limited to, classroom notes, films, photographs, electronic presentations, displays, slides, and tapes used in presenting the courses. The Contractor shall provide 4 electronic copies of all lesson plan documents on separate secure USB flash drives.

The Contractor shall assume that Authority personnel have no knowledge of the features of the buses. The Contractor shall provide course of instruction in two parts.

For the first part, the Contractor shall coordinate with appropriate Authority personnel and provide Familiarization & Orientation, High Voltage Safety and PPE, PMI (preventive maintenance inspection), and Servicing, Towing and Recovery procedure class concurrent with the delivery of each pilot bus and the first serial production bus. The Contractor shall provide training manuals for each subject and class. All parts shall be provided by the Contractor for the PMI class.

The second part of the instruction shall commence at the discretion of the Authority beginning approximately one (1) month after the delivery of the first serial production bus. At the Authority's discretion some of the scheduled training may be delayed towards the latter part of the warranty period. A final schedule for maintenance training shall be submitted to the Authority for approval as part of the Final Design Review meeting **(CDR 30).** Maintenance training shall include in-depth instruction covering at a minimum the maintenance activities normally performed at a garage on the following systems:

1. Traction Motor/Drive System
2. Theory of Operation
3. Energy Storage System (ESS)
4. Battery Chemistry Familiarization
5. High Voltage Charging Procedures
6. Fuel System
7. Fuel Alley/Service Procedures
8. Thermal Management Systems
9. High Voltage System
10. Low Voltage System
11. Bus Electrical System and Controls
12. Multiplex System including all CAN address definitions
13. Smart Bus/ITS Systems
14. Radio
15. Public Announcement (PA) System
16. Destination Signage
17. Bus Air System
18. Hydraulic System

19. Door Systems
20. Operator Controls
21. Mobility Aid Ramp and Mobility Device Securement Systems
22. Towing and Recovering including thermal event situational towing and recovery
23. Safety Procedures including High Voltage Safety
24. Fire Suppression System
25. Rear Axle Assembly, Including Suspension and Brakes
26. Front Axle Assembly, Including Steering, Suspension, and Brakes
27. HVAC System, Including Auxiliary Heater and any Floor Level Heating Units and any EPA Certifications Required for Handling Refrigerants
28. HVAC system major component replacement procedures to include hands-on soldering training
29. Thermo King GPCO system

The times and duration of the instruction periods, and the quantity of personnel available to attend class, shall be at the discretion of the Authority. The Authority shall attempt to make six (6) trainees available for eight hours per normal working day. The following minimum quantities of personnel to be instructed are provided as a guideline:

1. Engineers and supervisory personnel—30
2. Garage personnel—150
3. Maintenance Training Instructors—10

The length of the instruction for each individual shall not be less than 240 hours**. (CDR 30) (CDR 44)**

TS 5.6.4 Training Aids

The Authority shall be responsible for providing space for training aids. The Contractor shall supply full size mock-up and component assemblies including necessary supporting and display racks, for the Authority to use initially and on a continuous basis as training aids. The mock-ups may be board mounted to conserve space and to enhance conception of the actual operation of the sub-systems. Configuration of the training aid is subject to Authority approval. The following training aids shall be delivered prior to commencement of training programs:

1. Power Module — Completely dressed and mounted upon a stand for operation (not under load), comprised of a drive unit, ESS, and drive unit and ESS thermal management systems; to include full instrumentation, and capable of operation without any auxiliary power supply or interfaces. The module shall incorporate safety interlocks and permit frequent subcomponent removal and reassembly for training purposes.
2. Electrical System — Complete, full size, operational, board mounted, including multiplex system and interfaces with all electrical equipment. The Training Aid/Module shall be configured with a power cord that can be plugged into a 120 VAC power source for operational demonstration.
3. Compressed Air System — Complete with all valves and typical piping, operational, board mounted. The Training Aid/Module shall be configured with a power cord that can be plugged into a 120 VAC power source and shop compressed air supply, for operational demonstration.

a) Compressed Air System shall include:

Anti-Lock Brake System (including Automatic Traction Control - ATC) — all modules and valves mounted for demonstration of operation, testing and repair procedures.

4. Front and Rear Axle assemblies shall include:

   a) Front and Rear Brake assemblies individually mounted on a stand suitable for repeated disassembly and reassembly.

   b) Front axle shall include all steering arms and linkage

5. HVAC System — Complete top unit with motor driven compressor and water supply that is stand mounted so that the unit is operable. The Training Aid/Module shall be configured with a power cord that can be plugged into 220 3-phase VAC power for operational demonstration. Any floor / underseat heating units shall be provided with typical piping and controls, mounted independent of the top HVAC unit.

6. Door System — Complete door and operator assembly including sensitive edges and safety devices. Both front and rear door, if not identical, mounted on a stand that shall be configured with a power cord that can be plugged into a 120 VAC power source, and shop compressed air supply.

7. Destination Signage System — Front, side and rear sign units mounted with controller and Contractor supplied interfaces to Smart Bus Systems. The Training Aid/Module shall be configured with a power cord that can be plugged into a 120 VAC power source for operational demonstration.

8. Fire Suppression System — Complete stand mounted system with devices to allow safe, small-scale, demonstration of all functions. The Training Aid/Module shall be configured with a power cord that can be plugged into a 120 VAC power source for operational demonstration.

9. Mobility Aid Ramp — Stand mounted that allows operation and repeated disassembly and reassembly. The Training Aid/Module shall be configured with a power cord that can be plugged into a 120 VAC power source for operational demonstration.

10. PA System — Complete and operational with all controls, inside and outside speaker, and Contractor supplied interfaces to ITS. The Training Aid/Module shall be configured with a power cord that can be plugged into a 120 VAC power source for operational demonstration.

11. Auxiliary Heater — Complete to include diesel and electric, and operational unit. The Training Aid/Module shall be configured with a power cord that can be plugged into a 120 VAC power source for operational demonstration.

12. Smart Bus/ITS Systems — Vehicle logic systems and operator interface components, configured with a power cord to operate on 120 VAC power supply, in a desktop arrangement with simulated operational and failure modes.

    a) Smart Bus/ITS Systems should include:

    Computers and Software — All required hardware, software and connecting cables for servicing of bus systems including propulsion system, ESS, multiplex, ABS, destination signs and Smart Bus/ITS systems. Can be plugged into 120 VAC power for operational demonstration.

The Contractor shall supply three sets color-coded schematics of each of the above systems and integrated block diagrams of major equipment.

Training Aids must be approved by the MBTA Maintenance Training Department. The Authority reserves the right to choose the appropriate training aids and quantities as required based on the budget established in the basis of award **(CDR 45).**

TS 5.6.5 Overhaul Shop Training

One month after the delivery of the first production bus the Contractor shall provide a training program that shall permit satisfactory overhaul and repair of equipment normally performed at the Authority's overhaul (back) shop. In addition to the equipment listed in Section TS 5.6.3, the Contractor shall also provide training on the following equipment:

1. Energy Storage System (ESS)
2. Drive unit overhaul
3. Front axle overhaul
4. Rear axle overhaul
5. Auxiliary heaters
6. Steering box rebuilding
7. Bus body panel replacement and repair, to include repair of vertical and horizontal support structure and recommended post-accident structural inspection and repair guidelines
8. Air compressor overhaul
9. One of each type of motor / blower to include
    a. Traction motors
    b. HVAC blower motors (including evaporator and condenser motors, and air circulation motors/assemblies)
    c. Air compressor motor and assembly
    d. Power steering motor and assembly
10. One of each type of electronic circuit boards on assemblies.
11. Air Ride Operator's Seat refurbishment

Equipment overhaul training shall consist of three parts. **(CDR 30) (CDR 46).**

1. The first part shall last one month and shall be attended by thirty (30) management, engineering, and shop personnel. It shall begin at the completion of garage maintenance training.
2. The second part shall be a one (1) week "refresher course" during the warranty period of the last production bus and after the completion of the first part or at any time within the contract as chosen by the Authority. The refresher course shall be attended by thirty (30) personnel, not necessarily the same individuals attending the initial training. The agenda shall be provided by the Authority at least one (1) month prior to the beginning of the refresher course.
3. The third part shall be the factory training of two (2) Maintenance Instructors for both the ESS and drive unit overhaul and diagnostics. The Contractor shall provide ESS and drive unit overhaul training for the Maintenance Instructors at the respective vendor facilities. This training shall allow the Authority's Instructors to attain Factory Instructor Certification (FIC) in overhaul procedures, thus enabling the Authority's Instructors to certify additional repair personnel. The cost of factory training and certification of six (6) MBTA Maintenance Instructors is borne by the Contractor. The Authority retains responsibility of its personnel undergoing its FIC training

At the Authority's discretion some of the scheduled training may be delayed towards the latter part of the warranty period.

TS 5.6.6 First Responder Training

Concurrent with the delivery of the Pilot buses, the Contractor shall provide 'Train the Trainer" training to Authority personnel encompassing First Responder familiarization with BEBs and potential scenarios and safety concerns they may encounter. CDR 47

TS 5.6.7 Additional Training CDR 30

The Contractor shall provide training per the requirements of Technical Specification Attachment 3 *Mobile Closed Circuit Television System* and Attachment 4 *Communication Equipment*.

The Contractor shall provide virtual high voltage/PPE, safety, and bus operator, training modules in a digital format for continued Authority use. The Contractor shall submit the training modules for Authority review and approval and shall provide six copies of each of the approved modules on individual secure USB flash drives.

TS 5.6.8 Renewal Parts Inventory List and Parts Seminar

The Contractor shall provide a Renewal Parts Inventory List and a Renewal Parts Inventory Seminar to familiarize material management personnel with the bus components.

The Contractor shall submit a complete suggested parts inventory list, required to support this fleet with price detail to determine the total cost required. This Renewal Parts Inventory List must include parts that are not in inventory, as well as parts needed to support this fleet. This list must detail parts required to maintain the fleet, identifying the OPM vendor's name and address, OPM vendor part number, full part description, unit cost, anticipated lead time, and estimated annual usage and include both inventory and non-inventory items. The Renewal Parts Inventory List and Parts Number Index and related information shall be provided by the Contractor as part of the Final Design Review meeting **(CDR 32)**

Contractor shall provide updated parts pricing and lead times for Renewal Parts (TS 5.6.8) and Consumable Parts (TS 5.6.9) effective with, and provided on, the FAI date. The Contractor shall provide four (4) copies of the Renewable Parts and Consumable Parts and Pricing, each on separate secure USB flash drives (Kingston Data Traveler Vault Privacy 3.0 or latest revision secure flash drive) **(CDR 47)**

The Contractor shall conduct a Parts Seminar for one class not to exceed 25 people held during daylight hours at a location to be designated by the Authority. The course shall not exceed 30 hours, but no less than 12, and shall include both classroom and field instruction. The seminar shall be conducted within one month of delivery of the Pilot Bus. **(CDR 48)**

A draft seminar presentation shall be provided by the Contractor during the Final Design Review meeting. **(CDR 32)**

TS 5.6.9 Consumable Spare Parts

The Contractor shall submit a list of recommended Consumable Spare Parts as part of the Final Design Review meeting **(CDR 31)**. This list must detail parts required to maintain the fleet, identifying the vendor's name and address, the OPM vendor's part number, full part description, unit cost, anticipated lead time, and estimated annual usage and include both inventory and non-inventory items.

TS 5.6.10 Engineering / Technical / Service Representatives

The Contractor shall, at its own expense, provide competent technical service representatives to assist the Authority in the solution of engineering, technical, and design problems within the scope of this

Technical Specification, TS Attachments, and RFP 1F-22. The Contractor shall provide OEM qualified and experienced:

1. Engineering Support
2. Technical Specialist / Analyst
3. Technical Assistance
4. Facility technical support
5. Software and Firmware Assistance

TS 5.6.11 On-site Warranty Coordinator

The Contractor shall, at its own expense, have one or more competent technical Warranty Coordinators available on request to assist the Authority in the solution of Warranty and technical issues as they arise and for processing warranty claims, or design problems within the scope of the specifications that may arise during the warranty period. Additional Warranty Coordinator requirements are provided in RFP Section 9.

TS 5.7 Operating Environment

The bus shall be capable of being operated at the specified performance levels, and stored and maintained without impairment resulting from the natural or induced environmental conditions within which the Authority intends to operate the bus in passenger service.

The following climatic factors shall be used as design guidelines and shall be considered as operational requirements.

1. Temperature and Solar Load:

   Ambient air temperature:
   Minimum.....-20°F
   Maximum .....115°F

   Humidity:
   Minimum.....5%
   Maximum.....100%

2. Precipitation:

   Maximum rainfall rate.....4 inches per hour
   Maximum snowfall rate.....5 inches per hour
   Maximum snowfall accumulation ....18 inches

3. Wind:

   Maximum sustained speed .....40 mph
   Maximum gust speed.....70 mph

4. Air contamination: The vehicle shall operate as specified under air contamination levels which occur in the coastal environment that exists in the Authority's service area.

5. Road contamination: The vehicle shall operate as specified under the dust, trash, and leaf accumulation conditions experienced in the Authority's service area. Salt, sand, and other de-icing materials are frequently applied to streets during adverse winter weather conditions.

The bus shall achieve normal operation in temperature ranges of -20°F to 115°F, at relative humidity between 5 percent and 100 percent. Degradation of performance due to atmospheric conditions shall be minimized at temperatures below -20°F or above 115°F. If special equipment or procedures must be employed to precondition the ESS or start the bus when exposed to extreme weather conditions, the Bidder must incorporate the parameters and recommended procedures in the Maintenance and Operator Manuals and bring these issues to the attention of the Authority during the design review process.

Speed, gradeability, and acceleration performance requirements shall be based upon SAE J1634 adapted standards testing conditions. . Performance degradation at conditions other than the test standard shall not exceed 1 percent for each 3°F and 4 percent for each 1,000 feet of elevation above the standard. The interior climate control system shall perform in accordance with Section TS 42.

Actual localized temperatures and conditions within and under the bus body may be more severe than those listed. The Contractor shall be responsible for evaluating and advising the Authority if there are any special environmental factors to which its equipment may be sensitive, and that are not listed in this section.

TS 5.8 Noise, Vibration and Ride Quality

BEBs by their nature emit less noise than buses with internal combustion engines. TS 8.2 requires the Contractor to provide an appropriate artificial sound generator that is consistent with the intent and functionality of FMVSS No. 141 for the Authority's review and approval. TS 5.8.1 and TS 5.8.2 requirements shall apply.

TS 5.8.1 **Interior Noise**

The combination of inner and outer panels and any material used between them shall provide sufficient sound insulation so that a sound source with a level of 80 dBA measured at the outside skin of the bus shall have a sound level of 65 dBA or less at any point inside the bus. These conditions shall prevail with all openings, including doors and windows, closed and the accessories switched off.

The bus-generated noise level experienced by a passenger at any seat location in the bus shall not exceed 80 dBA. The driver area shall not experience a noise level of more than 75 dBA. Measurements of interior noise levels shall be taken in accordance with SAE J2805.

TS 5.8.2 Exterior Noise

Airborne noise generated by the bus and measured from either side shall not exceed 80 dBA under full power acceleration when operated at 0 to 35 mph at GVW. The maximum noise level generated by the bus pulling away from a stop under full accessory load, shall not exceed 83 dBA. The bus-generated noise at with full accessory load, shall not exceed 65dBA recorded with the propulsion system 'on' and the bus stationary (*curb idle test*). If the noise contains an audible discrete frequency, a penalty of 5 dBA shall be added to the sound level measured. All noise readings shall be taken 50 feet from, and perpendicular to, the centerline of the bus with all accessories operating at full load. The Contractor shall comply with the exterior noise requirements defined in local laws and ordinances identified by the Authority and SAE J366. The pull-away test shall begin with the front bumper even with the microphone. The *curb idle test* shall be conducted with the rear bumper even with the microphone.

TS 5.8.3 Vibration

The Contractor shall design components—electrical, mechanical, and other connections—to operate without degradation during and after exposure to vibration as encountered in normal service in the Authorities operating environment. Mechanical components shall be mounted to minimize transfer of vibrations to passengers.

TS 5.8.4 Ride Quality

The bus shall be free from objectionable vibration and shock. All equipment mounted in the passenger area shall be free from resonance to avoid annoying audible and visual distraction.

On poor quality road surfaces, the ride quality shall not contain excessive instability or bottoming when the bus is driven at posted speed. Upon request, the Contractor shall submit evidence, such as analysis and comparative tests, establishing that the design used produces a ride quality comparable to the best state of the art buses. Ride quality shall conform to these guidelines with the load ranging from curb weight to GVWR.

TS 5.9 Fire Safety

The bus shall be designed and manufactured in accordance with all applicable fire safety and smoke emission regulations. These provisions shall include the use of fire-retardant / low-smoke materials, fire detection systems, bulkheads, and facilitation of passenger evacuation.

The passenger compartment shall be separated from ESS, drive unit/motor, and auxiliary heater, compartments by fire-resistant bulkheads. The drive unit/motor or auxiliary heater compartment may include areas where combustion and exhaust system are housed. All bulkheads shall preclude or retard propagation of an ESS, drive unit, or auxiliary heater, compartment fire into the passenger compartment and shall be in accordance with the Recommended Fire Safety Practices defined in FTA Docket 90A, dated October 20, 1993. Only necessary openings shall be allowed in the bulkhead, and these shall be fire-resistant. Any passageways for the climate control system air shall be separated from ESS, drive unit, or auxiliary heater, compartments by fire-resistant material. Piping through the bulkhead shall have fire-resistant fittings sealed at the bulkhead. Wiring may pass through the bulkhead only if connectors or other means are provided to prevent or retard fire propagation through the bulkhead. Access panels in the bulkheads shall be fabricated of fire-resistant material and secured with fire-resistant fasteners. These panels, their fasteners and the bulkheads shall be constructed and reinforced to minimize warping of the panels during a fire that shall compromise the integrity of the bulkhead.

TS 5.9.1 Materials

All materials used in the construction of the passenger compartment of the bus shall be in accordance with the Recommended Fire Safety Practices defined in FTA Docket 90-A, dated October 20, 1993. FTA Docket 90-A certificates shall be provided to the Authority for review, at the Intermediate Design Review meeting **(CDR 26).** Materials entirely enclosed from the passenger compartment, such as insulation within the sidewalls and sub-floor, need not comply. In addition, smaller components and items, such as seat grab rails, switch knobs, small light lenses, door seals, window seals, steering wheel, steering column and escape hatches shall be exempt from this requirement.

TS 5.10 Fire Detection and Suppression System

The bus shall be equipped with a suitable means of automatically detecting and extinguishing fires, detect overtemperature situations, and detect ESS outgassing events that may cause unreliable or unsafe operation. The Fire Suppression system shall be capable of manual actuation by the bus operator. The bus operator’s manual actuation switch shall have a means to prevent accidental actuation of the suppression system.

At a minimum, all buses shall have a Fire Detection and Suppression System designed to prevent ESS thermal runaway, detect and eliminate ESS off-gassing, and provide fire detection and suppression in the auxiliary heater compartment.

(A) Actuation of the Fire Suppression system shall automatically isolate the ESS

(B) Fire Suppression system detection of fire and/or ESS outgassing shall automatically:

1. Transmit signal through a wireless discreet to the Authority's Operations Control Center (OCC)
2. Activate all four green emergency lights (TS 62.3)
3. Activate an audible alarm

(C) The Fire Suppression system shall be capable of communicating to the facility charging network to disconnect power between the bus and the charger, and signaling to the facility fire suppression system the bus/charger location

If the energy storage device is capable of releasing combustible gas, then this same system shall incorporate an integrated gas detection and alarm feature. ESS outgassing sensors shall be located inside all ESS modules. This system shall employ intrinsically safe detectors capable of reliable operation, alert, and shutdown to ensure safe operation.

The Fire Detection and Suppression System shall include an uninterruptable power supply (UPS) capable of sustaining operation for a period of at least 72 hours regardless of the primary power source state of charge and remain uninterrupted regardless of master run switch position. The quantity, location and technology for sensors, suppression agents, etc. shall be best practice for the intended application and environment.

Sensors shall be of the linear type, capable of measuring temperature and programmable at the controller. Fire suppression piping located in the immediate area(s) being protected shall be fireproof and capable of surviving gross thermal events. The subject piping shall include the flow path between the fire suppression bottle and nozzles, with metalized rigid/flexible stainless steel preferred. The system shall include a means to automatically monitor fire suppression storage container pressure and to provide low-pressure alerts to the integrated system controller/display.

The fire suppressant tank shall have a life of no less than 12 years.

The Contractor shall provide design and qualification documentation demonstrating the fire suppression system and suppression agent is of sufficient size and chemistry for all thermal event risk sources for this bus configuration, ESS battery chemistry, auxiliary heater, and all thermal event risk sources. The fire suppression system shall be presented to the Authority for review and approval **(Table 2, D13)**.

TS 5.11 Respect for the Environment

In the design and manufacture of the bus, the Contractor shall make every effort to reduce the amount of potentially hazardous waste. In accordance with Section 6002 of the Resource Conservation and Recovery Act, the Contractor shall use, whenever possible and allowed by the specifications, recycled materials in the manufacture of the bus.

TS 5.12 Lifetime Technical Support

When requested by the Authority, the Contractor shall provide technical support during the lifetime of the bus. Technical support shall include chassis and structural inspection, technology improvements and support, report generation, recommendations of repairs and/or modifications to include written repair/modification procedures. The Contractor shall also provide any service and parts bulletins, and parts supersessions.

II. DIMENSIONS

TS 6. Physical Size

With the exceptions of exterior mirrors, marker and signal lights, bumpers, fender skirts, and rub-rail, the bus shall have the following overall dimensions:

TS 6.1 Length

The length from bumper to bumper (outside edge) shall be 40 feet (+ 1 ft, -3 inches)

TS 6.2 Width

Body width shall be 102 inches (+0, −1 inch)

TS 6.3 Height

The maximum overall height shall be 131.5 in. including all rigid, roof mounted items such as HVAC equipment, ESS and propulsion systems, compartment/systems covers, etc.

TS 6.4 Step Height

TS 6.4.1 Boarding Step

A maximum of one step shall be required for passenger ingress and egress from the bus. The step in each doorway shall be in a fixed location relative to the floor of the bus. At the front door, the step up from street level shall not exceed 15 ½ inches, and the step up from street level at the rear door (s) shall not exceed 16 inches. Front and rear boarding step height measurements shall be with the bus at the design ride height and not kneeled.

TS 6.4.2 Interior Step

A maximum of two steps, with not more than 10-inch risers of uniform height, may be provided in the aisle rearward of the rear door post leading to a high-floor area in the rear of the bus. Steps shall be the width of the aisle as determined by the seating in the immediate area of the steps. Step structure shall be corrosion-proof throughout the service life of the bus. Each step shall simultaneously support 300-pound loads evenly distributed over any 6-inch wide section of the tread without permanent deformation and with elastic deflection of no more than 0.125 inches. Each step tread shall support a load of 500 pounds evenly distributed over the center half of the tread without permanent deformation. The steps shall be sloped only sufficient to preclude water accumulation on the steps. All corners in the step-area shall have radii no less than 1/4 inch to facilitate cleaning.

TS 6.5 Underbody Clearance

The bus shall maintain the minimum clearance dimensions as defined below and per the standard procedures of SAE Standard J1100 regardless of load up to the gross vehicle weight rating.

TS 6.6 Ramp Clearances

The approach angle is the angle measured between a line tangent to the front tire static loaded radius arc and the initial point of structural interference forward of the front tire to the ground.

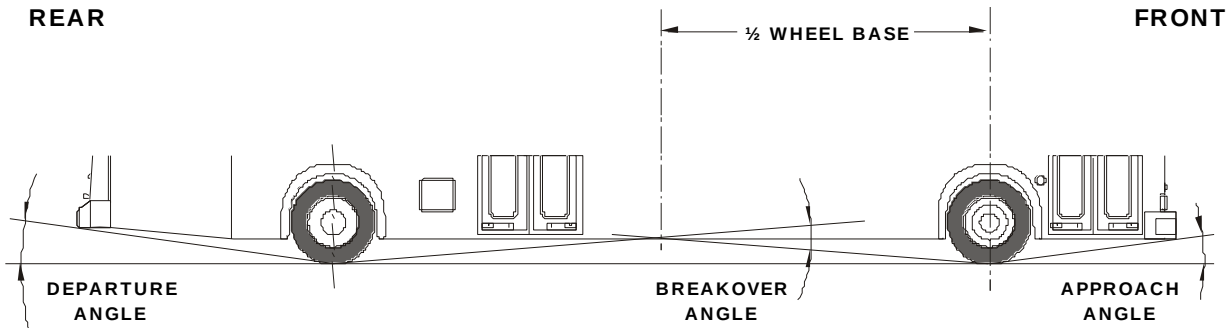
The departure angle is the angle measured between a line tangent to the rear tire static loaded radius arc and the initial point of structural interference rearward of the rear tire to the ground.

The breakover angle is the angle measured between two lines tangent to the front and rear tire static loaded radius and intersecting at a point on the underside of the vehicle that defines the largest ramp over which the vehicle can roll.

Table 4 provides the minimum ramp clearance requirements.

TABLE 4
Ramp Clearance Requirements

Angle	Requirement
Approach	8.6 degrees (min.)
Front breakover	8 degrees (min.)
Departure	8.6 degrees (min.)



TS 6.7 Ground Clearance

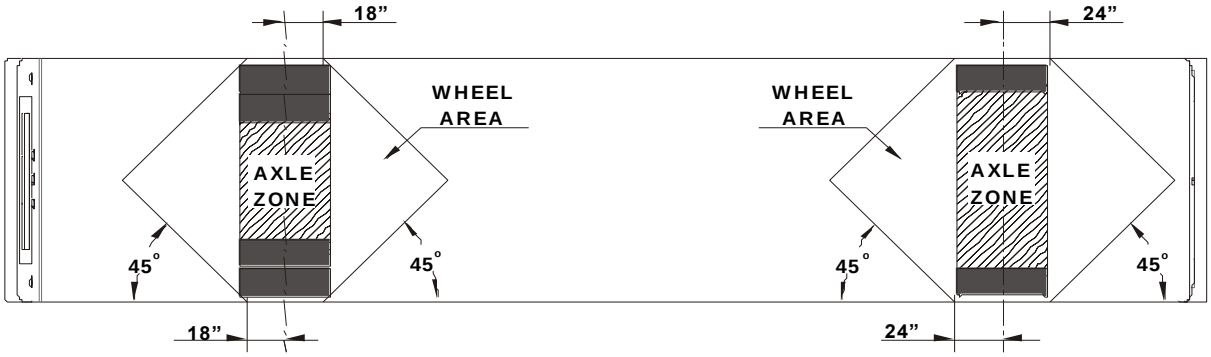
Ground clearance shall be no less than 8.6 in., (8 in. at jacking pad) except within the axle zone and wheel area. Any protrusion/part less than 9 in. ground clearance shall require the installation of a bumper/guard that provides appropriate protection against damage. The Contractor shall obtain specific Authority approval for each protrusion/part that extends beyond a 9 in. ground clearance. The design of a proposed bumper/guard shall be submitted for the Authority's review and approval.

Axle zone clearance, which is the projected area between tires and wheels on the same axial centerline, shall be no less than 5.4 in.

Wheel area clearance shall be no less than 8 in. for parts fixed to the bus body and 6 in. for parts that move vertically with the axles.

Non-compliant clearances must be identified and conveyed to the Authority. Non-compliances shall not be considered without appropriate protection for all non-compliant structure and components.

FIGURE 1
Transit Bus Minimum Road Clearance



TS 6.8 Interior Headroom

Headroom above the aisle and at the centerline of the aisle seats shall be no less than 78 in. in the forward half of the bus tapering to no less than 74 in. forward of the rear settee. At the centerline of the window seats, headroom shall be no lower than 65 inches. Headroom at the back of the rear bench seat may be reduced to a minimum of 56 in., but it shall increase to the ceiling height at the front of the seat cushion. In any area of the bus directly over the head of a seated passenger and positioned where a passenger entering or leaving the seat is prone to strike his or her head, padding shall be provided on the overhead paneling.

TS 6.9 Aisle Width

The minimum clear aisle width between pairs of transverse seats with all attached hardware shall be at least 24 in. The aisle width between the front wheelhouses shall be the largest size offered by the Contractor as a standard, and shall be at least 32 in.

The entire area between the front wheelhouses shall be available for all passengers and their mobility devices. The Contractor shall demonstrate the aisle width between the front wheelhouses is compliant with all ADA requirements through physical test using a box to simulate clearance envelope. For both pilot buses this test shall be performed with all accessories installed on the bus.

III. VEHICLE PERFORMANCE

TS 7. Altoona Test Performance

The propulsion system shall be sized to provide sufficient power to enable the bus to meet the defined acceleration, top speed, and gradeability requirements, and operate all electric accessories using actual road test results the Authority operating environment. Profiles used for Altoona tests shall be reviewed for evaluation purposes. The delivered bus shall meet the performance standards described in TS 8.

TS 7.1 Top Speed

The bus shall be capable of achieving a top speed of 65 mph on a straight, level road at GVWR with all accessories operating. The bus shall be capable of safely maintaining the vehicle speed according to the recommendations by the tire manufacturer.

Prior to release for shipment, the Contractor shall reprogram the bus to limit bus top speed to 55 mph.

TS 7.2 Gradeability

Gradeability requirements shall be met on grades with a surface friction coefficient of 0.3 or above at GVWR with all accessories operating. The propulsion system shall enable the bus to maintain a speed for a minimum of one minute for each the following conditions:

1. 40 mph on a 2-1/2-percent grade
2. 10 mph on a 10-percent grade
3. 7 mph on a 16-percent grade

TS 7.3 Acceleration

The propulsion and braking systems shall meet the performance requirements of the Authority's Operating Profile and Duty Cycle.

Braking application and performance shall remain consistent regardless of ESS State of Charge (SoC) or other variances related to regenerative braking.

The system shall be programmable to allow optimization of acceleration and deceleration rate. The baseline program shall be established through the Design Review process and requires Authority approval. Performance may be affected when reprogramming. The manufacturer shall supply the new performance data.

The acceleration shall meet the requirements in **Table 5** below and shall be sufficiently gradual and smooth to prevent throwing standing passengers off-balance. Acceleration measurement shall commence when the accelerator is depressed.

TABLE 5
Maximum Start Acceleration Times on a Level Surface[1]

Speed (mph)	Maximum time (seconds)
10	5
20	10
30	18
40	30
50	60
Top speed	

1. Vehicle weight = GVWR

TS 7.4 Jerk Rate

Jerk, the rate of change of acceleration, shall be minimized throughout the acceleration / deceleration range and shall be no greater than 0.3 g/second for a duration of a quarter-second or more. This requirement shall be achieved regardless of driver actions.

TS 7.5 Operating Range

The operating range of the bus when run on the Altoona Energy Economy Multi-Cycle Test shall be a minimum of 250 miles Manhattan, 275 miles Orange County, and 300 miles UDDS.

The Contractor shall provide documentation of the operating range for the bus as specified in this technical specification during the Pre-Production meeting.

Profiles used for Altoona tests shall be reviewed for evaluation purposes. The delivered bus must meet the performance standards described in TS 8.

TS 7.6 Energy Economy

Test results from the Altoona Energy Economy Test shall be provided to the Authority. Results shall include vehicle configuration and test environment information. Fuel economy data shall be provided for each operating profile. For Energy Economy evaluation, operating profiles are assumed to be defined by the Altoona Energy Economy Test.

4. Duty Cycles (avg speed)
5. Manhattan: 6.8 mph
6. Orange County: 12 mph
7. HD-UDDS: 18.86 mph
8. Idle time: 0 mph

Altoona Energy Economy Multi-Cycle Test as adapted from SAE J1634-2017 shall be utilized.

Profiles used for Altoona tests shall be reviewed for evaluation purposes. The delivered bus must meet the performance standards described in TS 8.

IV. PROPULSION

TS 8. Propulsion System (Electric)

The propulsion system shall be sized to provide sufficient power to enable the bus to meet the defined acceleration, top speed, and gradeability requirements, and operate all propulsion-driven accessories using actual road test results and computerized vehicle performance data.

The Contractor shall perform route profile analysis of all existing routes currently run out of the Authority's North Cambridge, Quincy, and Arborway facilities to demonstrate the Contractor's compliance with all Technical Specification performance requirements.

Existing route API and GTFS files are available at https://www.mbta.com/developers

The Contractor shall provide a detailed report to the Authority confirming the proposed BEB configuration shall meet all Technical Specification performance, charging, Agency Operating Profile, and Bus Operations requirements. The Contractor shall also provide their Route Profile Analysis, Battery Electric Bus and ESS Theory of Operation for review at the Pre-Production meeting. **(CDR 6).**

The propulsion system components shall be presented to the Authority for review and approval (**Table 2**, D15)

TS 8.1 Propulsion System Requirements

The bus shall be powered by an all battery electric propulsion system and conform to SAE J2910 and J2344. The propulsion system shall not be supplemented by any onboard range extenders, including but not limited to, internal combustion engines, gas turbines and/or hydrogen fuel cells. Function and operation of the bus shall be transparent to the bus operator and passengers. The OEM shall assure that the bus structure can successfully accept the installation of the propulsion system and be operated on the stated duty-cycle for a period of 14 years without a structural failure. At a minimum, the propulsion system shall comply with applicable local, state, and federal environmental, performance, safety, maintenance, and useful life requirements.

The Contractor shall affix labels on high-voltage devices to identify them as components conducting high-voltage potential. These labels shall be applied in such a way that they can be seen when access doors are opened or closed, so as to protect both emergency and maintenance personnel. (TS Attachment 1)

A detailed description of the propulsion system shall be provided by the Contractor. The description shall include a written narrative, a block diagram showing major propulsion system components, an illustration showing the physical layout of propulsion components and high-voltage wire routing within the vehicle, and a detailed wiring diagram and/or electrical schematic for the high-voltage system. The Contractor shall be required to provide a list of applicable industry standards that the proposed propulsion system meets.

TS 8.2 Safe Minimum Sound Level

During the design review process and in line with an Authority approved test procedure, the Contractor shall demonstrate and document the exterior vehicle noise (pull away, approach, and stationary (idle)). The Contractor shall provide an appropriate artificial sound generator that is consistent with the intent and functionality of FMVSS No. 141 and shall be Authority programmable/adjustable for sound type, level, and duration, for the Authority's review and approval. The noise requirements of TS 5.8.1 and TS 5.8.2 shall apply. **(CDR 6)**

TS 8.3 Propulsion System Service

The propulsion system shall be arranged so that accessibility for all routine maintenance is assured. No special tools, other than dollies and hoists, shall be required to remove the propulsion system or any

subsystems. However, the Authority shall recognize that properly rated test equipment and safe electrical work practices are essential when servicing high voltage components. All components requiring service or replacement shall be easily removable.

The Contractor shall provide diagnostic equipment including software and fault analysis and diagnostic documentation to allow Authority technicians to troubleshoot all Propulsion System Level (TS 75.2) components to the smallest serviceable unit. The Contractor shall provide the Authority with all diagnostic software, documentation, and equipment to accurately troubleshoot to the ESS individual cell level. Diagnostic software shall be user friendly and allow Authority technicians to review and perform analysis of data logs, run custom queries, view fault codes and fault code diagnostic trees, view logic, and view live data. Data shall be unencrypted and in a raw format.

The Contractor shall provide all specialty tools and diagnostic equipment required for maintaining the Propulsion System in accordance with Special Tools List (See TS Attachment 5).

TS 8.4 Primary Propulsion Unit (PPU) and Traction Motor

The definition of motor in the context of this specification assumes the device can provide or consume energy as well as provide or retard mechanical motion.

TS 8.5 Energy Storage System (ESS)

Design and performance shall be provided to the Authority. Energy storage shall consist of a battery system of a service proven commercial design capable of operating in the Authority's transit environment.

The primary charging of the Energy Storage System shall be accomplished by a pantograph down system compatible with SAE J 3105-1. The bus shall also be outfitted with rear curb side and rear streetside charging receptacles. The bus shall be configured to permit automatic charging.

The Contractor shall provide an ESS of sufficient size to meet the performance requirements identified below. The Contractor shall be responsible for performing evaluations of the Authority's route profiles, charging infrastructure, intended allowable time between run blocks for charging, and historic weather extremes, for input into the Contractor's calculations.

1. The ESS nameplate battery capacity shall be no less than 500 kWh with a useable capacity of 80%
2. At bus acceptance, each BEB shall operate no less than 110 miles in the extremes of the Authority's operating environment between depot charging events, with the bus loaded to gross load, with full accessory utilization (including HVAC and auxiliary heater)
3. During the seven year ESS warrantable period, the ESS useable capacity shall be sufficient for the BEB to operate for no less than 88 miles in the extremes of the Authority's operating environment between depot charging events, with the bus loaded to gross load, with full accessory utilization (including HVAC and auxiliary heater)
4. TS 8.5.1 shall be the basis for determining ESS State of Health (SoH) with the as delivered nameplate capacity being 100% and EOL below 80%
5. The Contractor's ESS SoH calculations shall ensure that 80% capacity is sufficient for the bus to meet TS 8.5.3
6. Any bus failing to meet the performance requirements of TS 8.5.3 or TS 8.5.4 shall be considered as 0% SoH
7. For the purposes of this Technical Specification, WEOL shall mean the same as EOL. A bus with 0% SoH shall be considered at the WEOL

8. ESS shall comply with ECE R100 Revision 2
9. ESS shall conform to applicable standards for the proposed chemistry (e.g., UN/DOT 38.3; SAE J2464)
10. ESS shall achieve full SoC, when beginning with 15% SoC, in ***four hours*** or less, when utilizing a 150 kW pantograph down charging system. Failure to meet this requirement shall deem the ESS to be at WEOL.
11. The Contractor shall provide external ESS SoC indication per TS 62.8

The ESS shall be end user serviceable with appropriate diagnostic tools as supplied with the special tools kit. A State of Health (SoH) parameter shall be viewable through diagnostic tooling that shows how much of the useful and intended life is left in the ESS (0-100% status). The Contractor shall provide documentation demonstrating a correlation and relationship between their SoH calculations and the operating and range requirements of TS 8.5

The ESS shall be equipped with an internal control module that shall be able to ensure that the cells, packs, and strings are balanced and never exceed minimum and maximum allowable limits, log data in an unencrypted and raw format, determine overall ESS health, monitor temperatures, provide input to the thermal management system, and provide full diagnostic capabilities by Authority technicians.

Thermal management shall be designed and implemented to ensure optimal life and performance of the ESS over the environmental operating range.

The ESS shall be located on the bus to optimize both interior space and vehicle weight distribution. The batteries shall be load-distributed within the bus to equalize weight between the wheels on the same axles and to achieve appropriate weight distribution between axles so as not to adversely affect handling of the bus.

ESS containers shall be designed to an IP 65 and IP 67 rating per IEC Standard 60529, and constructed to withstand the rigors of transit service for the 14 year service life of the bus. Additionally, ESS storage containers located in areas exposed to the environment shall also meet IP 65 and IP 69K standards. ESS container design shall be an integral part of the ESS thermal event prevention strategy and the container construction shall be of materials compatible with the battery chemistry. The ESS container and supporting/mounting structure shall pass 1000 hour salt spray tests in accordance with ASTM Procedure B-117 with no structural detrimental effects and no weight loss in excess of 1 percent. Impact and protrusion resistance testing of the ESS container shall meet the latest SAE standards. All electrical connections shall be fully shielded and hand-operable. Connector and cabling design shall be such that inappropriate or unsafe connections are prevented. Vent-and-fill system components for individual packs or containers shall not require any disassembly on removal or installation of the battery packs or containers. Pack design must comprehend the protection of battery cabling and vent/watering system components during pack removal and installation. The batteries, when installed, shall be secured to the chassis to prevent any movement that may cause damage or personal harm while the vehicle is in operation.

The Contractor shall deliver each bus with an installed and functioning ESS charged with sufficient usable energy for a full day of service (no less than 110 miles). The ESS shall be fully formed, installed and tested in accordance with the battery manufacturer's recommended practices. The Contractor shall provide documentation of ESS design, including containers, module bracing systems, thermal-management systems, battery-management systems, watering/venting systems, interconnections, fusing, and traction-controller and charger interfaces as part of the design review process.

The ESS shall be ARB certified and meet OBD requirements in affect as of this RFP 1F-22 NTP date.

TS 8.6 ESS System Safety

The bus body shall be designed and constructed to ensure that passengers and the operator shall not be exposed to high voltage. This design shall also minimize potential exposure to electrical current in the event of a vehicle accident. The vehicle and energy storage system shall be designed and constructed to prevent off gassing or fumes from the energy storage system from entering the interior of the bus.

The ESS and propulsion system design and configuration shall be optimized for safe and efficient maintenance. Batteries shall have manual disconnect switches with LOTO provisions.

The Contractor shall provide both automatic and manual ESS disconnect devices. Contactors shall be rated to interrupt the full load of the bus. Service and emergency manual disconnects must be included and their usage documented. Contractor shall provide a means to safely isolate the high-voltage battery during maintenance operations. Manual and automatic disconnects should open both poles of each physical battery pack.

The HV system and ESS shall include isolation protection between the HV and bus chassis system, to include automatic detection of isolation faults, alerts to the operator, diagnostic system, and appropriate action to prevent HV exposure to all personnel. Detection, alerting and vehicle control shall occur in accordance with SAE J2910. Detection shall be provided at two levels, as per J2910, and detection at any level shall be alerted to the operator and maintenance personnel.

The system described above may also be an integral part of the overall emergency shutdown system, with functions to include the following:

1. Offers a quick, safe, and organized means for the operator, maintenance personnel and/or first responders to shut down the HV system. The location of the master manual ESS disconnect switch shall be clearly identified on the bus exterior access panel and shall be accessible in less than 10 seconds for deactivation of the HV system. (refer to LV disconnect TS 34.1.7). The master manual ESS disconnect switch shall have no less than an IP 65 rating.
2. Shutting down the propulsion system shall include opening all HV contactors and disconnecting any devices that could provide HV during normal operation and including during charging.

Devices used to safely initiate shutdown shall be located within and outside the bus to satisfy ease of use by the first responders and maintenance and operations personnel and shall be clearly marked as to location and use.

In addition to manual use, this same functionality shall extend to the charging operation in the event of a fault sensed by the GFI, to also include termination of charge.

The Contractor shall perform Failure Mode and Effects Analysis (FMEA) and Quantitative Risk Assessment of the full high voltage battery system (ESS) and components to include an analysis of design, configuration, packaging, thermal management, SoC protection, charge management, and thermal event detection and prevention. The Contractor shall present the full document and data during the design review process for Authority review and approval consideration. **CDR 7**

The Contractor shall provide written confirmation from the ESS manufacturer attesting to the safety of the proposed battery system in the specified application and charging profile to include full disclosure and documentation of any and all relevant issues or prior incidents relating to safety.

The Contractor shall provide descriptions of all safety standards followed in the design and manufacture of the ESS, safety testing procedures used to validate the safety of the ESS operation in this application, and documented results of safety testing to confirm that standards have been met.

The Contractor shall provide documentation for of incident and safety procedure for use by first responders.

TS 8.7 High Voltage (ESS) Battery Management System (BMS)

The High Voltage Battery Management System must be designed to ISO 26262, as applicable, safety principles to control SoC, voltage, current and temperatures on a cell-to-cell level. and provide diagnostic output at the lowest field-serviceable element. The diagnostic output must be made available to the maintainer.

As a minimum, the ESS battery management system (BMS) must perform the following functions:

1. The BMS must be capable of monitoring the voltage of cells within each battery pack. The BMS must be able to read individual battery or block voltages at a frequency sufficient to ensure reliable, functional and safe operation.
2. The BMS must be capable of monitoring and controlling battery temperatures, mitigating damage to the battery and surroundings, and preventing thermal runaway.
3. The BMS must be capable of communicating when a battery fault (as defined by the battery manufacturer) has occurred and must be able to identify and communicate the location of the faulty battery in order to perform maintenance.
4. The BMS must be capable of engaging prudent safety interlocks when an unsafe energy storage system condition has been detected.
5. The BMS must be able to monitor the energy storage system SoC and SoH and provide information to the rest of the vehicle.
6. The BMS shall monitor, store, and export State of Health (SoH) and SoC live and historic data through the wireless gateway. Data shall be easy to view in a file format not requiring proprietary software
7. The BMS must be able to communicate all data real time to the bus level information system (reference TS 75) for storage and communication.

TS 8.8 ESS SoC Protection

The High Voltage BMS shall be configured to prevent a full depletion of the ESS. Load shedding shall not occur above 15% SoC. Progressive load shed shall derate auxiliary systems with the goal of protecting the ESS and maintaining sufficient charge for the bus to return to a charging facility. A system of warning lights and buzzers shall be located on the driver's dash alerting the driver to various low charge levels.

The Contractor shall submit their load shed strategy and driver alert system to the Authority for review. **(CDR 6)**

TS 8.9 High Voltage Cables

The High Voltage (HV) cable system (cables, terminals, clamps, and all other associated components) connecting various sub-systems within the propulsion system is considered a critical component of the propulsion system and shall last the 14 year service life of the bus without replacement. HV cables are to be appropriately sized for the current loads in the propulsion system and designed to minimize any electrical interference. All cables are to be of a bundled design that includes an outer jacketing the protects the individual cable from UV, abrasion, or other damage. All HV cable ground shielding (wire mesh or other) shall be protected from chafing, wear, and damage, whether from adjacent cables, clamps, shields, jacketing and/or any exterior or environmental source. HV Cables shall be routed in a manner to minimize cable damage due to heat, fluids, chafing, extreme bending, and fatigue. The clamping/securement strategy for all HV cables shall be robust in design and not require maintenance or replacement.

All *high voltage* electrical connectors shall meet the following minimum requirements:

1. IP 65 and IP 67 for all electrical connectors located outside of junction boxes
2. IP 67 for all electrical connectors located inside all compartments and junction boxes
3. IP 65 and IP 69K for all electrical connectors located in areas exposed to the environment such as the undercarriage

TS 8.10 ESS Charging

The primary charging of the Energy Storage System shall be accomplished by a pantograph down system compatible with SAE J 3105-1.

The bus shall also be outfitted with CCS (Combined Charging System) curb side and streetside charging receptacles capable of AC and DC charging and configured to SAE J1772 DC and/or SAE J3068 AC standards. Charge receptacle covers shall be side forward hinged configuration and completely flush with the side of the bus. Charge receptacle cover hinges are to be spring loaded to hold the covers closed.

The bus shall be configured to permit automatic charging for pantograph and plug-in charging modes. Automatic charging shall not require bus operator or mechanic input once the charger connection is made. The automatic charging system shall fully immobilize the bus, including the application of the braking system and disabling of the PPU and traction motors, through a seamless and tamperproof interface with all interlocks and safety devices.

To facilitate smart charging , each bus shall be configured with a unique vehicle identification number for recognition by on-route and depot charging systems, and viewable by Authority staff.

Throughout WEOL, the ESS shall achieve full SoC, when beginning with 20% SoC, in four hours or less, when utilizing a 150 kW pantograph down charging system.

The Contractor shall provide a detailed description of its ESS charging system , including all safety and interlock systems, compliance with all standards, and control of ESS charge rate and temperature.

The Contractor shall provide ESS charge time based for each charging mode (pantograph, AC and DC receptacles) to include recharge time based on SoC, SoH, and ambient temperature as part of the design review process.

.

TS 8.11 Anti-Rollback

A vehicle anti-rollback feature shall be provided to prevent the vehicle from inadvertently rolling in operation. In the event that the anti-rollback feature fails to keep the bus from rolling back, an audible alert that the vehicle is in anti-rollback and not being controlled by the hill holder feature shall be provided.

TS 9. Component Thermal Management Systems

Component Thermal Management Systems shall be of sufficient size to maintain optimal component operating temperatures under all conditions for the service life of the bus in the Authority's operating environment.

Component Thermal Management Systems shall meet the requirements stated in the TS 5.7 Operating Environment and shall be confirmed by qualification tests to meet the subsystem manufacturers' requirements for appropriate temperature control. Component Thermal Management Systems shall be equipped with individual full diagnostic packages including electronic detection devices to indicate overheating on the driver's control panel.

The Contractor shall provide evidence that each independent Thermal Management System loop has the capability to handle peak heat rejection from each thermal management circuit, including traction motor(s)/drive unit(s), energy storage system, propulsion control system, and the intermediate and low-

voltage power supply, with a partially clogged heat exchanger at maximum ambient temperature plus heat reflected off the pavement or adjoining bus structure/components. Each Thermal Management System loop shall meet the requirements for operation in the Authority's operating environment and shall be confirmed by qualification tests to meet the subsystem manufacturers' requirements for appropriate thermal management for each system loop.

ESS thermal management system shall interface with the high voltage battery management system to control ESS temperatures and prevent thermal runaway.

Additional Thermal Management system, and subsystem, requirements are identified in subsequent sections of this Technical Specification.

Component Thermal Management Systems design shall be submitted to the Authority during the design review process for review and approval. Sub-supplier signoffs and qualification test reports shall be required from cooling and propulsion equipment manufacturers **(Table 2, D11).**

TS 9.1 Coolant Reservoir

A means of determining satisfactory coolant level for each independent thermal management system loop shall be provided. A spring-loaded, push-button type valve or lever shall be provided to safely release pressure or vacuum in each independent system loop with both it and water fillers no more than 48 in. above the ground. All Coolant Reservoirs shall be equipped with sight glasses, each viewable and accessible through the same access door.

TS 9.2 Heat Exchanger

The bus shall utilize independent thermal management system loops to control ESS, traction motor/drive unit, inverters, and HVAC system temperatures. Where applicable, Heat Exchangers for each thermal management system loop shall be located near the component requiring thermal management so as to reduce excess plumbing. Heat Exchangers shall be protected by an easily cleanable screen designed to collect large debris. Heat Exchangers shall be designed to withstand thermal fatigue and vibration associated with installed configuration. Heat Exchanger cores shall be easily accessible for cleaning.

Heat Exchangers shall be of durable corrosion-proof construction with non-removable tanks.

TS 9.3 Heat Exchanger Mounting

The heat exchangers shall be installed in a manner to minimize core fouling caused by dirt, debris, leaves, etc., and protected to minimize introduction of road and other environmental debris. Heat Exchanger Mounting shall be presented by the Contractor and discussed as part of the Initial Design Review meeting.

TS 9.4 Heat Exchanger Piping and Hose

Heat Exchanger piping shall be stainless steel or brass tubing, and if practicable, hoses shall be eliminated. Necessary hoses shall be impervious to all bus fluids. All hoses shall be secured with stainless steel clamps that provide a complete 360-degree seal. The clamps shall maintain a constant tension at all times, expanding and contracting with the hose in response to temperature changes and aging of the hose material.

TS 9.5 Thermal Management System Fans

Thermal Management System Fans shall be electrically driven and temperature controlled.

Fans shall be of durable, corrosion-proof construction and designed so a mechanic can gain access for diagnosis or replacement. Fans and mounting brackets shall be designed to withstand the thermal fatigue and vibration associated with the installed configuration.

A screen guard must be installed on all electric motor fans per SAE J1308.

TS 9.6 Thermal Management System Coolant Pumps

Coolant shall be cycled through the HVAC system, ESS, traction motors/drive units, inverters, and other thermal management system loops by means of electric coolant pumps. Each pump shall be,

1. Sized for the required flow for the corresponding circuit
2. Brushless and seal-less design
3. Have a minimum maintenance-free service life for both the brushless motor and the pump of at least 40,000 hour in the MBTA operating environment
4. Variable speed, CAN controlled, with integrated programable controller
5. Have diagnostic capability accessible by Authority technicians
6. Of a corrosion proof design to both coolant and operating environment

TS 9.7 Thermal Management System Coolant Filters

Each Thermal Management System coolant loop shall be equipped with an appropriately sized, spin-on coolant filter. Coolant filters shall be easily accessible, and when replacing the coolant filters only the coolant in the filter shall be lost. Coolant filter replacement shall not require pressure filling or bleeding of the coolant loop.

TS 10. Propulsion System Component Mounting

All electrical/electronic hardware shall be serviceable. All electrical/electronic hardware mounted in the interior of the vehicle shall be resistant to tampering from passengers.

All electrical/electronic hardware mounted on the exterior of the vehicle that is not designed to be installed in an exposed environment shall be mounted in a protective enclosure. The hardware shall be mounted in such a manner as to protect it from the environment.

All electrical/electronic hardware and its mounting shall comply with the shock and vibration requirements of SAE J1455.

TS 10.1 Propulsion System Serviceability

The propulsion system shall be arranged for ease of access and maintenance. The Contractor shall list all special tools, fixtures or facility requirements recommended for servicing. All components requiring service or replacement shall be easily accessible and removable independent of the system removal.

If applicable, access shall be provided from under three passenger rear seats to service the drive unit or auxiliary heater. No special tools, other than dollies and hoists, shall be required to remove the drive unit.

Heat exchanger filler caps shall be hinged to the filler neck and closed with spring pressure or positive locks. All fluid fill locations shall be clearly and permanently labeled to help ensure correct fluid is added and all fillers shall be easily accessible with standard funnels, pour spouts, and automatic dispensing equipment. All lubricant sumps shall be fitted with magnetic-type drain plugs.

Color-coded labels shall be applied on all fluid lines, within the drive unit and auxiliary heater compartment at the fittings, to identify the fluids carried in lines. All labels shall be manufactured to ANSI/UL 969 Standards, withstand the Authority's operating environment (including cleaning procedures), printed to maintain legibility, positioned for unobstructed viewing, and remain affixed to the lines/hoses throughout the service life of the vehicle. The contractors proposed label and coding system shall be presented for review during the Design Review Process.

Drive unit and auxiliary heaters shall be equipped with sufficient filters for efficient operation and to protect the systems between scheduled filter changes. Where possible filters shall be of the spin-on,

disposable type. All filters shall be easily accessible, and the filter bases shall be plumbed to assure correct reinstallation.

All lines within the auxiliary heater and propulsion systems compartments shall be rigidly supported and shall be composed of Authority approved appropriate material. Flexible fluid lines shall be kept at a minimum and shall be as short as practical. They shall be routed or shielded so that failure of a line shall not allow fluid to spray or drain onto any component operable above the auto-ignition temperature of the fluid. Flexible lines shall be Teflon hoses with braided stainless steel jackets and shall have standard SAE or JIC brass or stainless steel, reusable, swivel, end fittings. Premium hoses of alternative construction may be used with specific prior approval of the Authority. Hoses shall be individually supported and shall not touch one another or any part of the bus.

TS 11. Hydraulic Systems

The hydraulic system shall demonstrate a mean time between repairs in excess of 100,000 miles. Hydraulic system service tasks shall be minimized and scheduled no more frequently than those of other major bus systems. All elements of the hydraulic system shall be easily accessible for service or unit replacement. Sensors in the hydraulic system shall indicate on the driver's diagnostic panel conditions of low hydraulic fluid level and low system operation pressure. Critical points in the hydraulic system shall be fitted with service ports so that portable diagnostic equipment may be connected, and permanently attached fittings equipped with serviceable sensors installed, for an off-board diagnostic system to monitor system operation.

A tamper-proof priority system shall prevent the loss of power steering during operation of the bus in the event of insufficient voltage conditions.

The hydraulic system shall operate within the allowable temperature range as specified by the lubricant manufacturer.

TS 11.1 Fluid Lines

All Hydraulic System Fluid Lines to include all pipes, tubing, and hose, shall be compatible with the hydraulic fluid and be rated at a working pressure limit that is safely above the maximum pressures encountered by the system.

All fluid Lines shall be rigidly supported to prevent chafing damage, fatigue failures, degradation, and tension strain. Fluid lines should be sufficiently flexible to minimize mechanical loads on the components. Fluid lines passing through a panel, frame or bulkhead shall be protected by grommets (or similar devices) that fit snugly to both the line and the perimeter of the hole that the line passes through to prevent chafing and wear, and shall not be bundled with or used to support electrical wire harnesses.

Fluid lines shall be as short as practicable and shall be routed or shielded so that failure of a fluid line shall not allow the contents to spray or drain onto any component operable above the auto-ignition temperature of the fluid.

All fluid lines and fittings shall be specified and installed per the manufacturer’s recommendations.

Appropriate clearance shall be designed between all fluid lines and fittings, to prevent rubbing, chafing, etc. This shall be a specific point of review by the Authority during the Pilot Bus FAI.

All flexible line (hose) assemblies shall have a permanent label affixed adjacent to a fitting at one end of each hose identifying the bus manufacturer’s part number (including revision identification); hose assembly OPM name, part number and date of manufacture; and industry standard type and size identifiers of the hose assembly. All labels shall be manufactured to ANSI/UL 969 Standards, withstand the Authority’s operating environment (including cleaning procedures), printed to maintain legibility, positioned for unobstructed viewing, and remain affixed to the lines/hoses throughout the service life of the vehicle.

Hydraulic fluid lines of the same size and with the same fittings as those on other piping systems of the bus, but not interchangeable, shall be labeled or marked "*For Use on the Hydraulic System Only*".

All fluid lines in high heat areas such as the Auxiliary heater compartment shall be composed of stainless steel piping where practicable, except in locations where flexible lines are required.

TS 11.2 Fittings and Clamps

All clamps shall maintain a constant tension at all times, expanding and contracting with the line in response to temperature changes and aging of the fluid line material. Fittings and clamps shall be designed for use in the environment where they are installed. For example, high-temperature resistant in the auxiliary heater compartment, resistant to road debris and de-icing material near the road surface, and so on.

Compression fittings shall be standardized to prevent the intermixing of components. Compression fitting components from more than one manufacturer shall not be mixed, even if the components are known to be interchangeable.

Appropriate clearance shall be designed for all fittings and clamps, to prevent rubbing, chafing, etc. This shall be a specific point of review by the Authority during the Pilot Bus FAI.

TS 12. Diesel Fuel System

The Diesel Fuel System shall be presented to the Authority for review and approval **(Table 2, D16).**

TS 12.1 Diesel Fuel Lines

Diesel Fuel System Lines, to include all associated pipe, tubing, hose, and connections shall be made from materials resistant to corrosion and protected from fretting and high heat.

Diesel fuel lines shall be compatible with, and capable of, carrying all classifications of ultralow sulfur diesel fuel recommended by the auxiliary heater manufacturer, including blends (such as blended #1 and #2 diesel) as well as biodiesel blends (up to B20).

Diesel fuel lines shall be accessible for ease of serviceability; and mounted, braced, and supported using "split-block" type or stainless steel P clamps insulated with silicon. All mounting clamps shall be mounted to a rigid structure to minimize vibration and shall be protected against damage, corrosion or breakage due to strain, rubbing, or wear. "Floating clamps" (not mounted to a rigid structure) shall not be permitted. Diesel fuel lines shall not be used to secure other components (wires, air lines, etc).

Diesel fuel lines shall be in conformance to SAE Standards.

All diesel fuel lines shall be labeled with durable adhesive labels with the words "DIESEL FUEL" no less than 3/16" in height and positioned for unobstructed viewing.

The labels shall be positioned on rigid fuel lines within 2" of the line entry into any compartment, or bulkhead passthrough, and again 2" from the termination and/or junction of the line with flexible lines. All labels shall be manufactured to ANSI/UL 969 Standards, withstand the Authority's operating environment (including cleaning procedures), printed to maintain legibility, and remain affixed to the diesel fuel lines throughout the service life of the vehicle.

Manifolds connecting diesel fuel containers shall be designed and fabricated to minimize vibration and shall be installed in protected locations to prevent diesel fuel line or manifold damage, from unsecured objects or road debris.

TS 12.2 Diesel Fuel Tank (s) Configuration & Installation

The Diesel Fuel Tank(s) shall have sufficient capacity to permit auxiliary heater system operation for 18 hours continuous hours service, in 0 (zero) Fahrenheit, in the Authority's operating environment.

The diesel fuel tank(s) shall be of stainless steel construction, easily removable for cleaning or replacement. and securely mounted to the bus to prevent movement during bus maneuvers.

The diesel fuel tank(s) shall be equipped with an external hex head drain plug, at least a 3/8 in. size, and shall be located at the lowest point of the tank(s). The diesel fuel tank(s) shall have an inspection plate or easily removable filler neck to permit cleaning and inspection of the tank(s) without removal of the tank from the bus.

The diesel fuel tank(s) shall be baffled internally to prevent fuel-sloshing regardless of fill level. The baffles or fuel pickup location shall assure continuous full fuel delivery on a 6 percent upgrade or downgrade for 30 minutes starting with no more than 10 percent of fuel over the unusable amount in the tank(s).

The materials used in mounting the diesel fuel tank(s) to the bus structure shall withstand the adverse effects of road debris, de-icing material, fuel, oils, and accumulation of ice and snow, for the service life of the bus.

TS 12.2.1 Labeling

The capacity, date of manufacture, manufacturer name, location of manufacture, and certification of compliance to Federal Motor Carrier Safety Regulation, shall be permanently marked on the diesel fuel tank(s). The markings shall be readily visible and shall not be covered with an undercoating material.

TS 12.2.2 Fuel Filler

The Fuel Filler shall be located as high as practical, and shall be on the curbside of the vehicle within 12 feet of the rear of the bus. The fuel filler shall allow filling at a rate of 40 gpm foam-free and shall have an Emco-Wheaton Posilock drybreak cap. An Emco-Wheaton or Authority approved equal filler neck shall be located behind an access door to prevent fuel from spilling onto the outside of the bus. The fuel filler door shall access the Posilock filler, be of side forward hinged configuration and open completely flush against the side of the bus. The fuel filler door hinge is to be spring loaded to hold the door open and closed.

V. STRUCTURE

TS 13. Structural Design

The structure of the bus shall withstand the transit service conditions found in the Authority's service area throughout its service life and shall operate with no maintenance for a minimum of 14-years or 500,000 miles, whichever comes first. Under normal conditions of transit service, the structure shall withstand fatigue damage that is sufficient to cause Class 1 or Class 2 failure. The structure shall also withstand impact and inertial loads due to normal street travel in the Authority's service area throughout the bus's service life without permanent deformation or damage.

TS 13.1 Altoona Testing

Prior to the start of any bus manufacturing or assembly processes, the structure of the proposed bus model shall have undergone appropriate structural testing and/or analysis, including successfully passing the complete regimen of FTA required Altoona tests. During the Design Review process and prior to assembly of the first bus, the OEM shall provide, for Authority review and approval, a completed passing report of Altoona testing for the proposed bus model along with scoring details, and details of any corrective action to address deficiencies, breakdowns and other issues identified during Altoona testing **(CDR 9).** The bus model tested shall match the bus model proposed for procurement, including structure, axles, and drive-train. Base model and partial Altoona test reports may be accepted at the Authority's discretion based upon FTA guidelines if the combination of these reports adequately represents the proposed bus model. Proposers shall include the relevant Altoona test report and/or a plan to complete testing with their proposal.

TS 13.2 Structural Validation

The structure of the proposed bus model shall have undergone structural testing at Altoona and an appropriate approved test report must have been submitted with the Contractor's bid. At the Pre-Production meeting, the Contractor shall present to the Authority any and all changes to the configuration tested at Altoona. Of particular interest to the Authority are any structural and suspension related component changes that may affect the structural durability, ride quality, reliability, and/or safety of the bus. The Authority may require FTA review of changes to the original proposed bus model and determination of configuration compliance to the Contractor's Altoona tested and passed prototype. The Contractor shall provide the MBTA with any and all completed test reports documenting and testing of these design changes at the Kickoff Meeting.

Prior to the Kickoff meeting, the Contractor shall have completed a shaker table test on the proposed bus to validate the bus structural design over a simulated 14 year and 500,000 mile service life based upon MBTA operating environment. The shaker table test shall be performed using data collected by the Contractor on an Authority severe duty cycle route of the Authority's choosing, and must be performed on the proposed bus loaded to gross load as defined in this technical specification. A full shaker table test report including modeling and vehicle failures and subsequent repairs shall be provided to the Authority at the Pre-Production meeting. The Contractor shall include in the report proposed changes designed to address reliability concerns and failures identified in the shaker table test. **(CDR 10)**

The Contractor shall fully instrument the Pilot buses and perform strain gauge testing on Authority specified routes as part of the Pilot Bus Design Qualification Test (Attachment 2) **(CDR 19).** Strain gauge testing shall be performed with the bus loaded to gross load. Deficiencies identified by strain gauge testing shall be addressed by the Contractor to include all updates to the Pilot bus and all production buses. Initial strain gauge testing shall be performed for no less than one month. Following corrective repairs, strain gauge testing shall restart from zero. Strain gauge testing shall be discontinued on each Pilot bus following successful completion of one month's strain gauge testing without an identified failure and/or deficiency.

The Contractor shall provide all details related to Structural Validation with supporting design Failure Mode and Effects Analysis (FMEA) documentation including Finite Element Analysis (FEA) report (inclusive of drawings, load conditions, analysis, review etc.), and shaker table report, which demonstrates all possible failure modes and the effects these failures may have on the bus Structure performance and function at the Pre-Production meeting. **(CDR 10)**

TS 14. Distortion

The bus, loaded to GVWR and under static conditions, shall not exhibit deflection or deformation that impairs the operation of the steering mechanism, doors, windows, passenger escape mechanisms, service doors, or other mechanical elements. Static conditions shall include the vehicle at rest with any one wheel or dual set of wheels on a 6 in. curb or in a 6 in. deep hole.

TS 15. Resonance and Vibration

All structure, body, and panel-bending mode frequencies, including vertical, lateral and torsional modes, shall be sufficiently removed from all primary excitation frequencies to minimize audible, visible or sensible resonant vibrations during normal service.

TS 16. Crashworthiness

The bus body and roof structure shall withstand a static load equal to 150 percent of the curb weight evenly distributed on the roof with no more than a 6 in. reduction in any interior dimension. Windows shall remain in place and shall not open under such a load. These requirements must be met without the roof-mounted equipment installed.

The bus shall withstand a 25 mph impact by a 4000-pound automobile at any side, excluding doorways, along either side of the bus with no more than 3 in. of permanent structural deformation at seated passenger hip height. This impact shall not result in sharp edges or protrusions in the bus interior.

Exterior panels below 35 in. from ground level shall withstand a static load of 2000 lbs. applied perpendicular to the bus by a pad no larger than 5 sq. in. This load shall not result in deformation that prevents installation of new exterior panels to restore the original appearance of the bus.

The Contractor shall perform Finite Element Analysis (FEA) demonstrating conformance with TS 16 and provide all documentation during the Pre-Production meeting. **(CDR 10)**

TS 17. Corrosion

The bus shall maintain structural integrity and nearly maintain original appearance throughout its 14 year (500,000 mile) service life in the MBTA's operating environment. The bus flooring, sides, roof, chassis, structure, axle, hardware and hardware installation, and suspension components, etc., shall be designed to resist corrosion or deterioration from all sources such as atmospheric conditions, environment, galvanic action, bus cleaning detergents, bus maintenance chemicals and cleaners, and de-icing materials, etc., for a period of 14 years or 500,000 miles, whichever comes first.

The bus body shall be constructed using only inherently corrosion resistant materials and fasteners such as stainless steel or composites to minimize deterioration.

All painted aluminum sheets shall be thoroughly cleaned and coated on the outside with a chip proof corrosion protective paint system prior to installation on the bus. All aluminum surfaces not otherwise protected and installed in areas subject to corrosion shall be anodized. Anodizing specifications shall require concurrence of the Authority.

All metallic joints shall be protected by application of zinc based corrosion protective paint system, or butyl tape sealer at assembly. Unless otherwise approved, all bolts, nuts, rivets, washers, and exposed linkage, shall be corrosion resistant stainless steel. Zinc-plated carbon steel hardware may be used only if approved by the Authority. If approved, zinc plating shall conform to the latest revision of ASTM-B-633, Type II, SC3 or SC4.

All joints and connections of dissimilar metals and/or dissimilar materials shall be corrosion resistant and shall be protected from galvanic corrosion. Representative samples of all materials and connections shall withstand a 1,000 hour salt spray test in accordance with ASTM Procedure B-117 with no structural detrimental effects and no weight loss in excess of 1 percent.

All structural and chassis materials shall be protected with corrosion resistant protective coatings. All corrosion resistant protective coatings shall protect all metallic and composite surfaces for the entire 14-year (500,000 mile) service life of the bus without a requirement for routine maintenance and/or reapplication. The Contractor shall be responsible for maintaining the integrity and performance of corrosion resistant protective coatings, to include any reapplication of protective coatings, for the service life of the vehicle.

TS 17.1 Corrosion Control Plan

The Contractor shall provide a Corrosion Control Plan **(CDR 16)** for review during the Pre-Production meetings which shall define recommended tasks required to maintain all structural and corrosion related warranties. The Contractor's Corrosion Control Plan shall be based upon the structure and materials meeting the requirements of TS 17.

TS 18. Towing

Permanent, vehicle mounted provisions shall be made for the Authority to recover the vehicle by lift towing at the front and rear using the Authority's stinger equipped recovery vehicle with MBTA standard lift tow attachments. Additionally, provisions shall be made at the front of the vehicle to allow attachment of a rigid tow bar that shall permit flat towing of the bus at curb weight. The Contractor's towing procedures shall ensure the traction motor cannot generate high voltage when the bus is towed or moved during a bus recovery procedure.

Each chassis mounted tow fixture shall withstand, without permanent deformation, tension loads up to 1.2 times the curb weight of the bus within 20° of the longitudinal axis of the bus. If applicable, the rear chassis mounted tow fixture shall not provide a toehold for unauthorized riders. The suspension system / axles shall not require special handling while the bus body is lifted for towing or while being towed. Removal of the bike rack is permitted for attachment of towing devices.

The Authority's standard towing adapters are designed to pin to tow eyes at the front and rear of the bus. Each towing adapter shall accommodate a tow hook with a one-inch throat to facilitate positioning of the towing adapter. The Contractor shall provide a minimum quantity of twelve (12) bus sets of towing/lifting adapters to enable vehicle recovery capability with the Authority's existing towing equipment, with delivery of material to coincide with delivery of the Pilot Bus.

Provisions shall be made to connect air from the towing vehicle to the service brake application valve. These connections shall be in a readily accessible location in the front and rear of the bus, and be identified by blue color coded glad hand connections. Provisions shall also be made to connect air from the towing vehicle to the wet tank and to the parking brake relay valve. These connections shall be in a readily accessible location in the front and rear of the bus, and be identified by red color coded glad hand connections. An IP 65 and IP 67 electrical receptacle connected to the bus exterior lighting system for towing purposes shall be provided near the front and the rear glad hands using an Authority approved connector.

As part of the Initial Design Review Meeting, the Contractor shall provide Towing and Lifting chassis mounted fixture design, towing adapter design, towing air system and electrical system connections, to the Authority for review and approval consideration. The Contractor shall provide towing procedures and documentation the towing adapter is compatible with existing Authority recovery vehicles **(CDR 21).**

Bus interior access panels to permit caging of the brakes shall be provided and shall meet the requirements of TS 67.1.

TS 19. Jacking

It shall be possible to safely jack up the bus, at curb weight, with a common 10-ton bottle or floor jack with or without special adapter, when a tire or dual set is completely flat and the bus is on a level, hard surface**,** without crawling under any portion of the bus. Jacking from a single point shall permit raising the bus sufficiently high to remove and reinstall any wheel and tire assembly. Jacking pads located on the axle or suspension near the wheels shall permit easy and safe jacking with the flat tire or dual set on a 6-inch high run-up block not wider than a single tire. Jacking and changing any one tire shall be completed by an Authority mechanic helper in less than 30 minutes from the time the bus is approached**.** The bus shall withstand such jacking at any one or any combination of wheel locations without permanent deformation or damage. Jacking pads shall be painted safety yellow for ease of identification.

TS 20. Hoisting

The bus shall be capable of being raised or lowered by two-post system, portable wheel lifts, drive-on platform lifts, bottle jacks, and floor jacks.

The bus axles or jacking plates shall accommodate the lifting pads of a two-post hoist system. Jacking plates, if used as hoisting pads, shall be designed to prevent the bus from falling off the hoist.

Other pads or the bus structure shall support the bus on jack stands independent of the hoist and shall be painted safety yellow for ease of identification.

The Contractor shall provide a detailed description of recommended hoisting procedures including safety stand positioning. The Contractor's procedures shall include but not be limited to hoisting under the following conditions:

1. Routine daily maintenance to include inspection, tire changes, brake inspection and service
2. Suspension and steering system maintenance and component replacement
3. Traction motor replacement
4. ESS service and replacement
5. Replacement of the rear or front axle assemblies

The Contractor shall provide all hoisting best practices and procedures as part of the Maintenance Practices Review **(CDR 33).**

TS 21. Floor

TS 21.1 Design

The floor shall be essentially a continuous plane, except at the wheel housings and platforms. Where the floor meets the walls of the bus, as well as other vertical surfaces such as platform risers, the surface edges shall be blended with a circular section of radius not less than 1/4 in. or installed in a fully sealed butt joint. Similarly, a molding or cover shall prevent debris accumulation between the floor and wheel housings. The vehicle floor in the area of the entrance and exit doors shall have a lateral slope not exceeding 2° to allow for drainage.

If floor level heating ducts are utilized, the top of the duct shall be blended with the wall with a molding or cove to prevent debris accumulation.

The floor design shall consist of two levels (bi-level construction). Aft of the rear door extending to the rear settee riser, the floor height may be raised to a height no more than 21 in. above the lower level, with equally spaced steps. An increase slope shall be allowed on the upper level, not to exceed 3.5° off the horizontal.

All measurements shall be with the bus at the design ride height and on a level surface.

TS 21.2 Strength

The floor deck may be integral with the basic structure or securely mounted on the structure to prevent chafing or horizontal movement.

The floor deck shall be reinforced as needed to support passenger loads. At GVWR, the floor shall have an elastic deflection of no more than 0.60 in. from the normal plane. The floor shall withstand the application of 2.5 times gross load weight without permanent detrimental deformation. The floor, with coverings applied, shall withstand a static load of at least 150 lbs. applied through the flat end of a 1/2 in. diameter rod, with 1/32 in. radius, at the minimum and maximum operating temperature, without permanent visible deformation.

Corrosion resistant fasteners shall be used to retain the floor and all floor fasteners shall be serviceable from one side only. All floor fasteners, including adhesives, shall maintain full integrity throughout the 14 year service life of the bus with no loss of retention strength. Tapping plates used for the floor fasteners shall be no less than the same thickness as a standard nut, and all floor fasteners shall be secured and protected from corrosion for the service life of the bus.

TS 21.3 Construction

The floor shall consist of the subfloor and the floor covering that shall last the service life of the bus. The floor as assembled, including the sealer, attachments and covering, shall be waterproof, non-hygroscopic and resistant to mold growth. The subfloor shall be of composite construction, and shall be resistant to the effects of moisture, decay, delamination, and core rot.

Composite subfloor shall be used throughout the bus. The composite subflooring shall meet or exceed all performance characteristics of ¾ inch 7-ply Marine grade plywood and capable of meeting the specified smoke and flammability requirements of 49 CFR 571.302. The Contractor's proposed flooring design and installation shall be submitted to the Authority for review and approval.

If required, tapping plates / blocks for mounting seats, stanchions, and other equipment shall be attached to or embedded in the panels in a manner as approved by the Authority and the flooring material supplier. All exposed edges of the floor panels, including openings for ducts and conduits, and joints between panels, shall be waterproofed and sealed prior to installation. All access hatch openings shall be properly reinforced with an Authority approved supporting frame / structure.

To the maximum extent possible floor panels shall be comprised of pieces as large as possible, and shall extend the full width of the vehicle with transverse joints located only over structural members. No transverse joints shall be used in the entrance and exit ways. Before applying the floor covering, all voids, fastener heads, and cracks between floor panels shall be filled with a fire retardant, two-part epoxy, leveling compound, and the floor sanded smooth and true within 1/16 in. in 3 feet in any direction.

The Contractor shall provide appropriate technical documentation related to the flooring system as part of the design review process. Documentation shall include material specifications, installation procedures, and recommended repair / maintenance practices **(Table 2, D2).**

TS 22. Platforms

TS 22.1 Driver's Area

The covering of platform surfaces and risers, except where otherwise indicated, shall be the same material as specified for floor covering. Trim shall be provided along top edges of platforms unless integral nosing is provided.

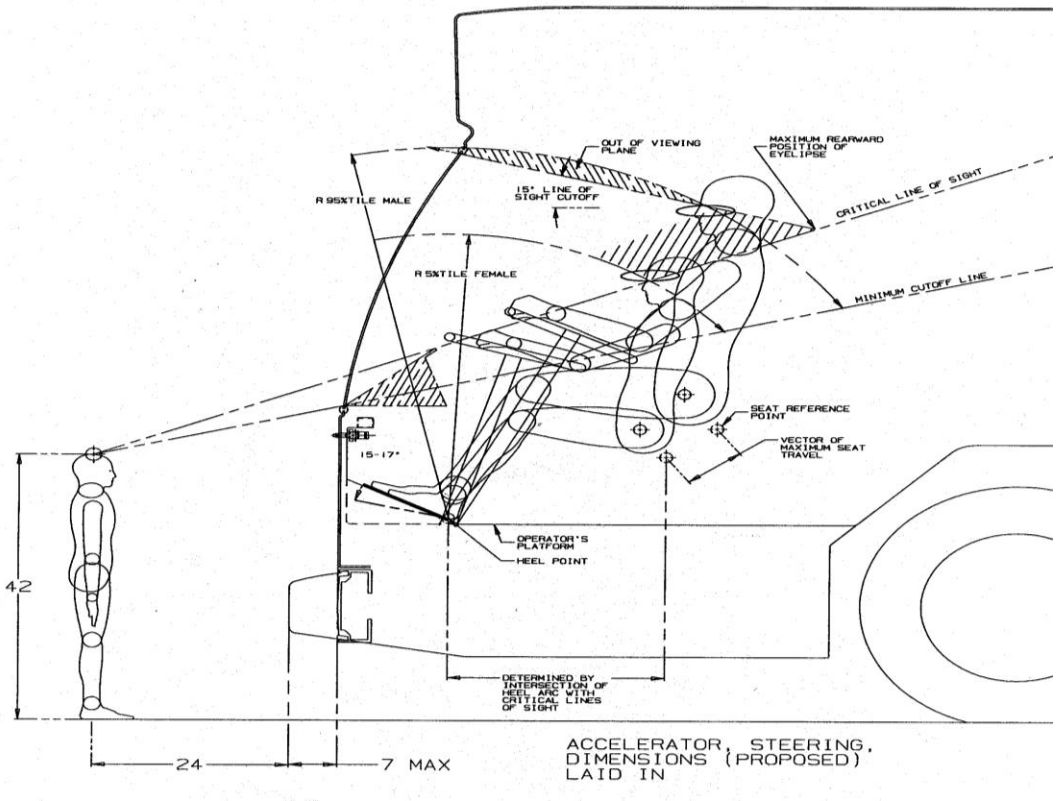
TS 22.2 Driver's Platform

The driver's platform shall be of a height such that, in a seated position, the driver can see an object located at an elevation of 42 in. above the road surface, 24 in. from the leading edge of the bumper. Notwithstanding this requirement, the platform height shall not position the driver such that the driver's

vertical upward view is less than 15°. A warning decal or sign shall be provided to alert the driver to the change in floor level**. Figure 2** illustrates a means by which the platform height can be determined, using the critical line of sight.

All measurements shall be with the bus at the design ride height and on a level surface.

FIGURE 2
Determining Platform Height



TS 22.3 Farebox Platform

Farebox placement should minimize impact to passenger access and minimize interference with the driver's line of sight.

The farebox platform shall be suitably robust to support the farebox used in the Authority's revenue fleet. Contractor to install the Scheidt & Bachman mounting system, compatible with latest farebox configuration, or Authority approved equal. Reference Section TS 66, Fare Collection. The farebox platform must be of sufficient height to allow for servicing of the farebox wiring harnesses.

If the driver's platform is higher than 12 in., then the farebox is to be mounted on a platform of suitable height to provide accessibility for the driver without compromising passengers' access.

Stanchions shall be located around the farebox.

Stanchions, farebox, and farebox mount shall not interfere with the driver's protection door, or adversely affect operator access to the driver's compartment.

For reference, the dimensions of the mounting plate to be installed on each bus shall be approximately 9-15/16" x 9-15/16" x 3/8". Confirmation of final dimensions shall be the responsibility of the Contractor. The farebox mounting area shall be reinforced as necessary to provide a sturdy mounting platform rated for 200 lbs. in a dynamic load condition (approximate weight of a farebox in passenger service operation) and to prevent farebox shaking.

The farebox platform shall be easily removable with basic hand tools by Authority technicians to coincide with the planned phase in of the Cubic fare collection system and subsequent removal of fare boxes. The removal of the farebox platform shall not result in uneven flooring, gaps in floor covering, or holes in the floor or vertical panels.

The Contractor shall design the farebox platform to be removable and shall provide a retrofit 'kit' for each bus to include all items needed to seal any openings and provide a uniform and clean appearance, relocation of grabrail and driver's safety barrier components (as required), and instructions for the retrofit. If the driver's platform is higher than 12 in., then the farebox retrofit kit shall include a step of suitable height to provide accessibility for the driver without compromising passenger and mobility device access. The Contractor's retrofit kit design shall be submitted as part of **CDR 13**, and all kits delivered in conjunction with Capital Spares.

TS 22.4 Rear Step Area to Rear Area

A rear step area shall be provided along the center aisle of the bus to facilitate passenger traffic between the upper and lower floor levels. This step area shall be cut into the rear platform and shall be approximately the aisle width, a minimum 12 in. deep and approximately half the height of the upper level relative to the lower level. The horizontal surface of this platform shall be covered with skid-resistant material with a visually contrasting nosing and shall be sloped slightly for drainage. A placard or inlay shall be provided at the immediate platform area to alert passengers to the change in floor level.

TS 23. Wheel Housing

Sufficient clearance and air circulation shall be provided around the tires, wheels, and brakes to preclude wheel end component overheating when the bus is operating on the design operating profile. Wheel housings shall be constructed of stainless steel. Wheel housing in a monocoque composite buses of a chassis-less one piece design must meet the same performance and impact requirements.

Wheel housings, as installed and trimmed, shall withstand impacts of a 2 in. steel ball with at least 200 ft-lbs. of energy on the exterior surfaces without penetration.

Interference between the tires and any portion of the bus shall not be possible in maneuvers up to the limit of tire adhesion with weights from curb weight to GVWR. Wheel housings shall be adequately reinforced where seat pedestals are installed. Wheel housings shall have sufficient sound insulation to minimize tire and road noise and meet all noise requirements of this specification.

Design and construction of front wheel housings shall allow for the installation of a radio or electronic equipment storage compartment on the interior top surface, or its use as a luggage rack.

The finish of the interior front wheel housings shall be scratch-resistant and complement interior finishes of the bus to minimize the visual impact of the wheel housing. If fiberglass or plastic interior wheel housings are provided, then they shall be color-impregnated to match interior finishes. The lower portion extending to approximately 10 to 12 in. above the floor shall be equipped with scuff-resistant coating or stainless steel trim. Interior wheel housing trim shall be designed and securely mounted to prevent any hazards to passengers and specifically passengers who use mobility devices/wheelchairs.

The front curbside wheel housing shall have a horizontal assist mounted on the top portion of the housing no more than 4 in. higher than the wheel well housing.

VI. CHASSIS

TS 24. Suspension

TS 24.1 General Requirements

The front and rear suspensions shall be pneumatic type. The basic suspension system shall last the service life of the bus without major overhaul or replacement. Adjustment points shall be minimized and shall not be subject to a loss of adjustment in service. Routine adjustments shall be easily accomplished by limiting the removal or disconnecting the components. **(Table 2, D28)**

TS 24.2 Alignment

All axles should be properly aligned to promote even tire wear, promote energy economy, lessens operator fatigue, and for the vehicle to track accurately. Alignment shall be adjustable by the Authority. Alignment settings shall not be subject to inadvertent changes while the bus is in service.**(Table 2, D26)**

TS 24.3 Springs and Shock Absorbers

TS 24.3.1 Suspension Travel

The suspension system shall permit a minimum wheel travel of 2.75 in. jounce-upward travel of a wheel when the bus hits a bump (higher than street surface), and 2.75 in. rebound-downward travel when the bus comes off a bump and the wheels fall relative to the body. Elastomeric bumpers shall be provided at the limit of jounce travel. Rebound travel may be limited by elastomeric bumpers or hydraulically within the shock absorbers. Suspensions shall incorporate appropriate devices for automatic height control so that regardless of load the bus height relative to the centerline of the wheels does not change more than 1/2 in. at any point from the height required. The safe operation of a bus cannot be impacted by ride height up to 1 in. from design normal ride height. **(Table 2, D28)**

TS 24.3.2 Damping

Vertical damping of the suspension system shall be accomplished with service proven adjustable hydraulic shock absorbers mounted to the suspension arms or axles and attached to an appropriate location on the chassis. Damping shall be sufficient to control bus motion to three cycles or less after hitting road perturbations. The shock absorber bushing shall be made of elastomeric material that shall last the life of the shock absorber. The damper shall incorporate a secondary hydraulic rebound stop. **(Table 2, D28)**

TS 24.3.3 Kneeling

A kneeling system shall lower the entire curbside of the bus a minimum of 2 in. during loading or unloading operations, regardless of load up to GVWR, measured at the longitudinal centerline of the entrance door and exit doors. The floor height at the entrance and exit door (s) threshold centerlines shall not exceed 9.2” when the bus is kneeled. The kneeling control shall provide the following functions:

1. Downward control must be held to allow downward kneeling movement.
2. Release of the control during downward movement must completely stop the lowering motion and hold the height of the bus at that position.
3. Upward control actuation must allow the bus to return to normal floor height without the driver having to hold the control.
4. Activation switch designed to provide independent operation of the streetside and curbside kneel functions and prevent simultaneous curbside and streetside kneeler operation.
5. Streetside kneeling is only required for buses with streetside boarding

The brake and throttle interlock shall prevent movement when the bus is kneeled. The kneeling control shall be disabled when the bus is in motion. The bus shall kneel at a maximum rate of 1.25 in. per second at essentially a constant rate. After kneeling, the bus shall rise within 4 seconds to a height permitting the bus to resume service and shall rise to the correct operating height within 7 seconds regardless of load up to GVWR. During the lowering and raising operation, the maximum vertical acceleration shall not exceed 0.2 g, and the jerk shall not exceed 0.3 g/second.

An indicator visible to the driver shall be illuminated until the bus is raised to a height adequate for safe street travel. An audible warning alarm with an IP68 rating shall sound simultaneously with the operation of the kneeler to alert passengers and bystanders. Audible alarms shall be located near the front door for curb side kneeling and near the streetside exit door for streetside kneeling. A warning light with a minimum 2.5 in. diameter amber lens, mounted near the curbside of the front door for curbside kneeling and near the streetside exit door for streetside kneeling, shall be provided that must blink when the kneel feature is activated. Kneeling functions shall not be operational while the mobility devices/wheelchair ramp is deployed or in operation. **(Table 2, D28)**

TS 25. Wheels and Tires

TS 25.1 Wheels

All wheel and tire assemblies shall be interchangeable on any location on the bus. Wheels shall be compatible with tires in size and load-carrying capacity. Front wheels and tires shall be balanced as an assembly per SAE J1986.

Wheels shall meet GVWR and GAWR ratings.

Wheels and rims shall be hub-piloted and shall resist rim flange wear.

Steel wheels shall be powder-coated with a thickness not to exceed 3.5 mil on any surface. Appropriate testing shall be conducted, and documentation of powder coating thickness shall be provided, by the Contractor as requested by the Authority.

Standard non-locking lug nut, Arvin Meritor Metric Flange Wheel Nut M22 x 1.5 THD, or Authority approved equal shall be used.

The Contractor shall provide and install *orange* Zafety lug nut locks on all lug nuts. A full set of green Zafety wheel locks shall be shipped loose with each bus.

TS 25.2 Tires

The tires shall be provided under a lease agreement between the Authority and the tire supplier. The Contractor shall ensure the tires are the appropriate size and load range for the vehicle.

With the bus loaded to GVWR and weight distribution conforming to gross load seated and standee design spacing, and tires inflated to bus manufacturer’s recommended tire pressure, load on any tire at shall not exceed the tire and wheel supplier’s rating.

Wheel and tire ratings shall meet axle manufacturer GAWR, and vehicle GVWR, with the tires inflated to the bus manufacturers recommended air pressure.

Tires with a low rolling resistance designed to improve energy economy are encouraged.

Due to an existing agreement between the Authority and Michelin North America Inc., the Contractor shall be furnished with new low profile radial tires for mounting and installation by the Contractor. The Contractor shall apply an approved lubricant to each rim prior to mounting the tire assembly. The tires shall be so mounted that the position of the valve stem shall locate the tire brand number inward, except the outside rear which shall be outward. The valve stems shall be those recommended by Michelin or approved equal, approximately 3" long with 13º bend. The rear wheel tire stems shall be aligned opposite

each other at the rim opening to permit ease of service and fitted with extensions as needed to ensure ease of inside tire inflation.

The Contractor shall be required to give the Michelin a minimum of sixty-days advance notice of their tire requirements. The Contractor shall be responsible for damage to or loss of tires while they are under the Contractor's control.

TS 26. Steering

Hydraulically assisted steering, with an electric driven hydraulic pump, shall be provided. The steering gear shall be an integral type with the number and length of flexible lines minimized or eliminated. **(Table 2, D26)**

TS 26.1 Steering Axle

The front axle shall be solid beam, non-driving, with a load rating sufficient for the bus loaded to GVWR and shall be equipped with grease type front wheel bearings and seals.

All friction points on the front axle shall be equipped with replaceable bushings or inserts and, if needed, lubrication fittings easily accessible from a pit or hoist.

Ackermann design shall reduce tire wear, minimize turn radius, and optimize driver control during all operating conditions. The steering geometry of the outside (frontlock) wheel shall be within 2° of true Ackerman up to 50 percent lock measured at the inside (backlock) wheel. The steering geometry shall be within 3° of true Ackerman for the remaining 100 percent lock measured at the inside (backlock) wheel.

Alternate front steering and suspension configurations of a proven design that meet load requirements may be provided to the Authority for approval consideration.

(Table 2, D26)

TS 26.2 Steering Wheel

TS 26.2.1 Turning Effort

Steering effort shall be measured with the bus at GVWR, stopped with the brakes released, on clean, dry, level, commercial asphalt pavement, and the tires inflated to recommended pressure.

Under these conditions, the torque required to turn the steering wheel 10° shall be no less than 5 ft-lbs. and no more than 10 ft-lbs. Steering torque may increase to 30 ft-lbs. when the wheels are approaching the steering stops, as the relief valve activates.

Power steering failure shall not result in loss of steering control. With the bus in operation, the steering effort shall not exceed 55 lbs. at the steering wheel rim, and perceived free play in the steering system shall not materially increase as a result of power assist failure. Gearing shall require no more than seven turns of the steering wheel lock-to-lock.

Caster angle shall be selected to provide a tendency for the return of the front wheels to the straight ahead position with minimal assistance from the driver. **(Table 2, D26)**

TS 26.2.2 Steering Wheel, General

The steering wheel diameter shall be no less than 19.5 in.; the rim diameter shall be 7/8 to 1¼ in. and shaped for firm grip with comfort for long periods of time. Steering wheel grip shall not be covered with foam or padding. Steering wheel configuration shall be submitted for Authority approval as part of the Design Review process.

Steering wheel spokes and wheel thickness shall ensure visibility of the dashboard so that vital instrumentation is clearly visible at center neutral position (within the range of a 95th-percentile male, as

described in SAE J1050). Placement of steering column must be as far forward as possible, but either in line with or behind the instrument cluster. **(Table 2, D26)**

TS 26.2.3 Steering Column Tilt

The steering column shall have full tilt capability with an adjustment range of no less than 40° from the vertical and easily adjustable by the driver and shall be accessible by a 5th percentile female and 95th percentile male. **(Table 2, D26)**

TS 26.2.4 Steering Wheel Telescopic Adjustment

The steering wheel shall have full telescoping capability range, adjustable and suitable for comfortable and ergonomic positioning for a 5th percentile female through a 95th percentile male. **(Table 2, D26)**

Table 6 below provides the steering wheel height relative to the angle of slope at both minimum and maximum telescopic height adjustments.

TABLE 6
Steering Wheel Height[1] Relative to Angle of Slope

At Minimum Telescopic Height Adjustment (29 in.)		At Maximum Telescopic Height Adjustment (5 in.)	
Angle of Slope	**Height**	**Angle of Slope**	**Height**
0 deg	29 in.	0 deg	34 in.
15 deg	26.2 in.	15 deg	31.2 in.
25 deg	24.6 in.	25 deg	29.6 in.
35 deg	22.5 in.	35 deg	27.5 in.

– 1. Measured from bottom portion closest to driver.

TS 27. Drive Axle

The bus shall be driven by a heavy-duty axle with a load rating sufficient for the bus loaded to GVWR. The drive axle shall have a design life to operate for not less than 300,000 miles in the Authority's operating environment without replacement or major repairs. The lubricant drain plug shall be magnetic type. If a planetary gear design is employed, the oil level in the planetary gears shall be easily checked through the plug or sight gauge. The axle and driveshaft components shall be rated for both propulsion and regenerative braking modes with respect to duty cycle.

The drive shaft shall be guarded to prevent hitting any critical systems, including brake lines, bus floor or the ground, in the event of a tube or universal joint failure.

Drive axles with integral and axle mounted drive motors shall be equipped with shielding to prevent corrosion and damage to motors, harness, and cooling systems and shall require no more maintenance than the sum of the individual components in a classic configuration (e.g., separate axle and drive motors). Documented industry proven serviceability, reliability, maintainability, and performance of drive axles with integral and axle mounted drive motors in a similar operating environment is required. **(Table 2, D27)**

TS 27.1 Hubodometer

The Contractor shall furnish and install one Veeder-Root (less tenths), or Authority approved equal, drive-less type Hubodometer on the curbside rear axle flange of the appropriate type for the wheel and tires installed. The Hubodometer shall have the following minimum requirements: six digits, 3/16- high by 1/8-inch wide numerals, Lexan cover with steel base, tamperproof and lifetime lubrication.

TS 28. Turning Radius

The outside body corner turning radius shall not exceed 44 feet. **(Table 2, D26)**

TS 29. Brakes

The braking systems in the vehicle shall conform to all applicable design and performance standards in FMVSS 571.121, Massachusetts 220 CMR 155.03 (12), and Massachusetts 49 CFR 393.41(a), (b), and (c).

The brake system shall be presented to the Authority for review and approval **(Table 2, D18)**.

TS 29.1 Actuation

Service brakes shall be controlled and actuated by a compressed air system. Force to activate the brake pedal control shall be an essentially linear function of the bus deceleration rate and shall not exceed 75 lbs. at a point 7 in. above the heel point of the pedal to achieve maximum braking. The heel point is the location of the driver's heel when his or her foot is rested flat on the pedal and the heel is touching the floor or heel pad of the pedal. The ECU for the ABS system shall be protected, yet in an accessible location to allow for ease of service.

The total braking effort shall be distributed among all wheels in such a ratio as to ensure equal friction material wear rate at all wheel locations. Manufacturer shall demonstrate compliance by providing a copy of a thermodynamic brake balance test upon request.

TS 29.2 Anti-lock Braking (ABS) and Automatic Traction Control (ATC)

Buses shall be equipped with an advanced anti-lock braking (ABS) and automatic traction control (ATC) systems fully integrated with the propulsion system. These systems shall be microprocessor controlled and designed to facilitate vehicle stability, controlled braking during emergency situations or adverse conditions, prevent wheel spin or lock up or loss of steering control.

The ABS/ATC system shall include easily accessible wheel speed sensors and controls for each wheel position.

ABS/ATC systems using wiring to connect the control module, wheel speed sensors, and modulator valves, shall have wiring harnesses routed and marked (whether by color codes or connector configuration) to eliminate crossed connections.

Activation of the ABS or ATC system shall disable the regenerative braking system only during an ABS / ATC system actuation event.

TS 29.3 Friction Material

The brake friction material shall comply with Washington State's RCW Title 70, Chapter 70.285.080 (3) and 70.285.030 which provide a schedule for the reduction of copper and other materials in-line with the provisions of EPA's 2015 Copper Free Brake Initiative (aka Better Brake Rule).

In order to aid maintenance personnel in determining extent of wear, a provision such as complete brake pad wear indicator shall be clearly visible from the hoist or pit without removing backing plates.

No remote brake wear indicator shall be required.

TS 29.4 Hubs and Discs

Replaceable wheel bearing seals shall run on replaceable wear surfaces or be of an integral wear surface sealed design. Wheel bearing and hub seals and unitized hub assemblies shall not leak or weep lubricant when operating on the design operating profile for the duration of the axle manufacturer's warranty. Wheel hubs shall utilize grease (type to be approved by the Authority) to lubricate wheel bearings.

The bus shall be equipped with disc brakes on all axles, and the brake discs shall allow machining of each side of the disc to obtain smooth surfaces per manufacturer's specifications.

The brake system material and design shall be selected to absorb and dissipate heat quickly so that the heat generated during braking operation does not glaze the brake pad or disc.

TS 29.5 Parking / Emergency Brake

The parking brake shall be a spring-operated system, actuated by a valve that exhausts compressed air to apply the brakes. The parking brake may be manually enabled when the air pressure is at the operating level per FMVSS 121.

An emergency brake release shall be provided to release the brakes in the event of automatic emergency brake application. The driver shall be able to manually depress and hold down the emergency brake release valve to release the brakes and maneuver the bus to safety. Once the driver releases the emergency brake release valve, the brakes shall engage to hold the bus in place. Air to the emergency brake release system shall be provided by a dedicated emergency air tank.

Spring brakes shall be capable of being "caged" to facilitate maintenance road service / towing.

Anti-compound brake system design shall be incorporated to prevent simultaneous application of service and spring brakes.

TS 29.6 Regenerative Braking

In addition to traditional mechanical friction service braking, the bus shall be equipped with regenerative braking designed to improve energy efficiency and extend brake lining service life. The application of regenerative braking shall cause a smooth blending of both regenerative and service brake function.

The regenerative braking system shall be capable of capturing braking energy and storing it in the ESS.

During regenerative braking, the mechanical / pneumatic braking system shall also be engaged. The purpose of this requirement is to periodically exercise mechanical braking components in service. Activation of the ABS or ATC system shall disable the regenerative braking system only during an ABS / ATC system actuation event. The regenerative braking system including regenerative braking level setpoints shall be evaluated and finalized during the Pilot Bus Testing and Demonstration program, and implemented on all production buses.

An explanation of the Regenerative Braking system shall be included in the Contractor's Battery Electric Bus Theory of Operation **(CDR 6).**

TS 29.7 Brake Performance & Testing

All buses shall receive a Massachusetts Department of Public Utilities (DPU) inspection prior to acceptance which includes brake testing per 220 CMR 155.03 (12) :

Each motor bus shall have two separate braking systems with independent operations. They shall be designed in such a way that failure of any one part of either system will not deprive the bus of an effective brake acting on at least two wheels. One braking system shall consist of a power brake as provided for in M.G.L. c. 90 §, 7, acting on at least four wheels and arranged in such a way as to be operated by the foot. It shall be capable of stopping the bus within a distance of 25 feet when moving at a speed of 20 miles per hour on a dry, level road. A second braking system shall consist of an emergency brake which shall be capable of stopping a bus within a distance of 60 feet when moving at a speed of 20 miles per hour on a dry, level road. Buses employing a braking system complying with 49 CFR 393.41(a), (b) and (c) shall employ a parking brake which will hold a bus stationary headed up or down with a full load on a 20% grade.

Brake function testing shall be performed with regenerative braking turned off.

The contractor shall provide all details related to the braking system, to include regenerative braking, with supporting design Failure Mode and Effects Analysis (FMEA) documentation, which demonstrates all

possible failure modes and the effects these failures may have on braking system performance and function. **(CDR 10)**

TS 30. Interlocks

TS 30.1 Brake and Accelerator Interlocks

To prevent opening front and/or rear passenger doors while the bus is in motion, a speed sensor shall be integrated with the door controls to prevent the front and/or rear doors from being enabled or opened unless the bus speed is less than 2 mph.

An accelerator interlock shall lock the accelerator in the "closed" (zero throttle) position, and a brake interlock shall engage the service brake system to stop movement of the bus in the following conditions:

1. When the driver's door control is moved to:
    a) A rear door enable or open position; or
    b) A rear door panel is opened more than 3 in. from the fully closed position (as measured at the leading edge of the door panel), or
    c) If an air dump valve (located at the doors) is actuated
2. The wheelchair ramp is activated or not stowed, or
3. Drive system in "neutral" position
4. The kneeling function has been activated
5. Parking brake is applied
6. Vehicle is charging
7. Any high voltage compartment access door is open

The interlock engagement shall bring the bus to a smooth stop and shall be capable of holding a fully loaded bus on a 6 percent grade, with the propulsion system on (in either forward or reverse mode), until the interlocks are released. These interlock functions shall be active whenever the vehicle master run switch is in any run position.

Brake and accelerator interlocks shall be supplied with supporting design Failure Mode and Effects Analysis (FMEA) documentation, which demonstrates that failure modes are of a failsafe type, thereby never allowing the possibility of release of interlock while an interlocked door is in an unsecured condition, unless the door master switch has been actuated to intentionally release the interlocks.

If a door interlock is active and the parking brake is not set, an alarm shall be sounded if the operator leaves the driver's seat.

TS 31. Pneumatic System

The pneumatic system shall be presented to the Authority for review and approval **(Table 2, D18)**.

TS 31.1 General

The bus air system shall operate the air-powered accessories and the braking system with reserve capacity. New buses shall not leak down more than 5 psi over a one hour period of time as indicated on the dash gauge. Starting pressure for this test must be 130 psi minimum.

Provision shall be made to apply shop air to the bus air systems. Quick disconnect fittings shall be easily accessible and located in the motor compartment and near the front bumper area for towing. Retained caps shall be installed to protect fittings against dirt and moisture when not in use. Air for the compressor shall be filtered. The air system shall be protected per FMVSS 121.

TS 31.2 Air Compressor

The electrically driven air compressor shall be sized to charge the air system from 40 psi to the governor cut-off pressure in less than 2 minutes.

Air is to be collected from as clean of a source as is possible and filtered before being supplied to the air compressor intake per the compressor OEM requirements. The filter shall be mounted in a location to avoid excessive accumulation of road and other debris and to provide easy access for maintenance. The required maintenance intervals for lubrication and filter replacement shall be no less than 20,000 miles. The compressor shall not require disassembly for repair or maintenance at intervals no less than 100,000 miles.

The air compressor mounts, structure, and air fittings shall be corrosion resistant.

Air compressor noise shall not exceed 75 dBa at 1 meter with the compressor at full rpm and load.

TS 31.3 Air Lines and Fittings

Air lines, except necessary flexible lines, shall conform to the installation and material requirements of SAE Standard J1149 for copper tubing with standard, brass, flared or ball sleeve fittings, or SAE Standard J844 for nylon tubing if not subject to temperatures over 200 °F. The air on the delivery side of the compressor where it enters nylon housing shall not be above the maximum limits as stated in SAE J844. Nylon tubing shall be installed in accordance with the following color-coding standards:

1. **Green:** Indicates primary brakes and supply.
2. **Red:** Indicates secondary brakes.
3. **Brown:** Indicates parking brake.
4. **Yellow:** Indicates compressor governor signal.
5. **Black:** Indicates accessories.

Line supports shall prevent movement, flexing, tension, strain, and vibration. Copper lines shall be supported to prevent the lines from touching one another or any component of the bus. To the extent practicable and before installation, the lines shall be pre-bent on a fixture that prevents tube flattening or excessive local strain. Copper lines shall be bent only once at any point, including pre-bending and installation. Rigid lines shall be supported at no more than 5 ft. intervals. Nylon lines may be grouped and shall be supported at 30 in. intervals or less.

The compressor discharge line shall be flexible convoluted copper or stainless steel line, or may be flexible Teflon hose with a braided stainless steel jacket. Other lines necessary to maintain system reliability shall be flexible Teflon hose with a braided stainless steel jacket. End fittings shall be standard SAE or JIC brass or stainless steel, flanged, swivel-type fittings. Flexible hoses shall be as short as practicable and individually supported. They shall not touch one another or any part of the bus except for the supporting grommets. Flexible lines shall be supported at 2 ft. intervals or less.

All lines and hose interior diameter surfaces shall be free of all foreign substances to prevent a reduction of flow and/or premature failure of connected components. Air lines shall be installed and secured to eliminate air leaks.

All air lines shall be routed to prevent water traps to the extent possible. Grommets or insulated clamps shall protect the air lines at all points where they pass through understructure components.

The air system shall be protected by a pressure relief valve set at 150 psi, and shall be equipped with check valves and pressure protection valves to assure partial operation in case of line failures.

T-fittings shall be installed in all airlines regulated by air pressure regulators to facilitate testing for proper pressure.

TS 31.4 Air Reservoirs

All air reservoirs shall meet the requirements of FMVSS Standard 121 and SAE Standard J10 and shall be equipped with drain plugs and guarded or flush type drain valves. Major structural members shall protect these valves and any automatic moisture ejector valves from road hazards. Reservoirs shall be sloped toward the drain valve. All air reservoirs shall have drain valves that discharge below floor level with lines routed to eliminate the possibility of water traps and/or freezing in the drain line.

TS 31.5 Air System Dryer

An air dryer shall prevent accumulation of moisture and oil in the air system. The air dryer system shall be a Bendix AD9 twin tower, or Authority approved equal.

The air system shall be equipped with an air dryer located before the no. 1 air tank and as far from the compressor as possible to allow air to cool prior to entering the air dryer. The air dryer shall be equipped with a heated automatic drain valve to prevent blockage due to icing. The air dryer shall be located in an area that is adequately protected from road debris or any other hazards that may interfere with the operation of the air dryer. Air dryer shall be located in an unobstructed area such that maintenance and desiccant cartridge replacement shall be performed with standard hand tools without the removal of the dryer assembly from the bus. The air dryer shall have spin-on cartridges. The required maintenance interval for air dryer service shall be no less than 1 year in the Authority's operating environment.

TS 31.6 Air System Component Manufacturer's Application and Installation Signoff

The Contractor shall perform an analysis of the air system for the Authority's operating environment to include:

1. Compressor manufacturer's application and installation signoff
    a. Specification and data sheet
    b. Design Life
    c. Voltage and power demand
    d. Compressor cooling/heating system
    e. Air build rate
    f. Duty cycle for the bus in this Technical Specification
    g. Installation location
    h. Noise
    i. Discharge line to air dryer design, configuration, and installation
    j. Maintenance intervals meet or exceed TS requirements
2. Air Dryer manufacturer's application and installation signoff
    a. Specification and data sheet
    b. Duty cycle for the bus in this Technical Specification
    c. Installation location
    d. Discharge line to air dryer design, configuration, and installation
    e. Maintenance intervals meet or exceed TS requirements
3. Air system FMEA

The Contractor shall submit the air system analysis to the Authority for review and approval consideration as part of the design review process. **(CDR 19)**

VII. ELECTRICAL, ELECTRONIC AND DATA COMMUNICATION SYSTEMS

TS 32. Overview

The electrical system shall consist of vehicle low and high voltage battery systems and components that generate, distribute, regulate, and store power throughout the vehicle.

Electronic devices are individual systems and components that process and store data, integrate electronic information or perform other specific functions.

The data communication system consists of the bi-directional communications networks that electronic devices use to share data with other electronic devices and systems. Communication networks are essential to integrating electronic functions, both on board the vehicle and off.

Information level systems that require vehicle information for their operations or provide information shall adhere to SAE J1939 data standard.

Data communications systems are divided into three levels to reflect the use of multiple data networks:

1. Propulsion System level
2. Information level
3. Multiplex level

TS 32.1 Modular Design

Design of the electrical, electronic and data communication systems shall be modular so that each electronic device, apparatus panel, or wiring bundle is easily separable from its interconnect by means of connectors.

TS 33. Environmental and Mounting Requirements

The electrical system and its electronic components shall be capable of operating in the area of the vehicle in which they shall be installed and comply with vibration and shock requirements as recommended in SAE J1455.

Electrical and electronic equipment shall not be located in an environment that shall reduce the performance or shorten the life of the component or electrical system when operating within the design operating profile.

The Contractor shall provide recommendations from component manufacturers and subsystem suppliers regarding methods to prevent damage from voltage spikes generated from welding, shorts, etc.

Electric and electronic subsystems and components shall meet or exceed the electronic noise control requirements of TS 77 .

TS 33.1 Hardware Mounting

The mounting of the hardware shall not be used to provide the sole source ground, and all hardware shall be isolated from potential EMI / RFI, as referenced in SAE J1113.

All electrical / electronic hardware mounted in the interior of the vehicle shall be inaccessible to passengers and hidden from view unless intended to be viewed. The hardware shall be mounted in such a manner as to protect it from splash or spray.

All electrical / electronic hardware mounted on the exterior of the vehicle that is not designed to be installed in an exposed environment shall be mounted in a sealed enclosure.

All electrical / electronic hardware and its mounting shall comply with the shock and vibration requirements of SAE J1455.

TS 34. General Electrical Requirements (CDR 16)

TS 34.1 Low Voltage Batteries

TS 34.1.1 Low-Voltage Batteries (12V/24V)

Odyssey or Authority Approved Equal Group 31 Series deep-cycling sealed non-spillable maintenance free absorbed glass mat (AGM) batteries shall be provided. Each battery shall have a minimum of 1000 cold cranking amps (CCA) at 0 °F and withstand the extremes of the Authority's operating environment . Low voltage battery quantity and configuration shall ensure vehicle waking, "starting", and operation of all low voltage accessories .

Batteries shall be load tested within three days prior to bus shipment.

Battery manufacturing dates must be within 3 months of bus shipment dates.

Positive and negative terminal ends shall be different sizes.

TS 34.1.2 Low Voltage Battery Management System

The low voltage system shall have a battery management system (BMS) installed. At a minimum, the system shall monitor battery current flow, individual battery temperature, charge voltage, individual battery state of charge, battery charge equalization, provide fault detection and communication on the CAN network, and be able to disconnect the battery from the electrical system. BMS charge rate shall be set for AGM batteries.

The low voltage BMS shall ensure sufficient battery charge is available to 'wake' the system and 'start' the bus. To prevent excessive low voltage battery drainage while the bus is shut down, the low voltage BMS shall disconnect the batteries to ensure sufficient charge is available to wake the bus. The low voltage BMS shall not disconnect low voltage batteries while the bus is in operation, during programmed 'sleep' modes, or when any safety critical or emergency notification system is activated.

The Contractor shall provide the Authority with all diagnostic software and programs for low voltage system component fault detection and diagnosis.

TS 34.1.3 Battery Cables

The battery terminal ends and cable ends shall be color-coded with red for the primary positive, black for negative and another color for any intermediate voltage cables. Positive and negative battery cables shall not cross each other, shall be flexible, and shall be sufficiently long to reach the batteries with the tray in the extended position without stretching or pulling on any connection and shall not lie directly on top of the batteries. Except as interrupted by the master battery switch, cables shall be continuous with connections secured by bolted terminals and shall conform to strand and insulation specification requirements of SAE Standard J1127 for the extremes of the Authority's operating environment. All battery cables shall be sized for the circuit load. Battery cable terminal ends shall be crimped and soldered per TS 34.3 .

TS 34.1.4 Jump Start

A Whitaker plug, equipped with a dust cap and adequately protected from moisture, dirt, and debris, shall be provided to boost the low voltage batteries in the event of an insufficient battery charge. The location shall be subject to approval by the Authority.

TS 34.1.5 Battery Compartment

The battery compartment shall prevent accumulation of snow, ice, and debris on top of the batteries and shall be vented and self-draining. It shall be accessible only from the outside of the vehicle. All components within the battery compartment, and the compartment itself, shall be protected from damage

or corrosion from the electrolyte. The inside surface of the battery compartment's access door shall be electrically insulated, as required, to prevent the battery terminals from shorting on the door if the door is damaged in an accident or if a battery comes loose. The battery compartment temperature should not exceed battery manufacturers specification.

The vehicle shall be equipped with a 12 VDC and 24 VDC quick disconnect switch(es). The battery compartment door shall conveniently accommodate operation of the 12 VDC and 24 VDC quick disconnect switch(es).

The battery quick disconnect access door shall be identified with a decal.

The battery hold-down bracket shall be constructed of a nonconductive and corrosion-proof material (plastic or fiberglass).

This access door shall not require any special locking devices to gain access to the switch, and it shall be accessible without removing or lifting the panel. The door shall be forward facing flush-fitting and incorporate a spring tensioner or equal to retain the door in a closed position when not in use.

The batteries shall be securely mounted on a stainless steel tray that can accommodate the size and weight of the batteries. The battery tray, if applicable, shall pull out easily and properly support the batteries while they are being serviced. The tray shall allow each battery cell to be easily serviced. A locking device shall retain the battery tray to the stowed position. Contractor shall provide a safety lock, subject to Authority approval.

If not located in the drive unit/motor compartment, the same fire-resistant properties must apply to the battery compartment. No sparking devices should be located within the battery box.

TS 34.1.6 Auxiliary Electronic Power Supply

If required, gel-pack, or any form of sealed (non-venting) batteries used for auxiliary power are allowed to be mounted on the interior of the vehicle if they are contained in an enclosed, non-airtight compartment and accessible only to maintenance personnel. This compartment shall contain a warning label prohibiting the use of lead-acid batteries.

TS 34.1.7 Master Battery Switch

The location of the low voltage master battery switch shall be clearly identified on the exterior access panel, be accessible in less than 10 seconds for deactivation, have no less than an IP 65 rating, and prevent corrosion from fumes and battery electrolyte when the batteries are washed off or are in normal service.

Turning the low voltage master switch off with the propulsion system operating during an emergency shall shut off the bus and shall not damage any component of the electrical system. The LV master switch shall be capable of carrying and interrupting the total circuit load and disconnecting and isolating the ESS.

Turning off the low voltage master switch shall not disable any emergency notification system, fire detection system, or ESS outgassing and temperature monitoring systems.

The batteries shall be equipped with a single LV master switch for disconnecting both 12 VDC and 24 VDC power.

TS 34.1.8 Low-Voltage Generation and Distribution

The low-voltage generating system shall maintain the charge on fully charged batteries through a DC/DC converter and controlled by the low voltage battery management system.(TS 34.1.2)

Voltage gauges and charge system malfunction indicator lights will be provided on the operator's dash.

Dedicated power and ground shall be provided as specified by the component or system manufacturer. Cabling to all equipment must be sized to supply the current requirements with no greater than a 2.5 percent volt drop across the length of the cable.

The Authority reserves the right to require the Contractor to submit cable size and load calculations during the design review process.

TS 34.1.9 Circuit Protection

All circuits shall be protected by current-limiting devices such as circuit breakers, fuses or solid-state devices sized to the requirements of the circuit. The circuit breakers or fuses shall be easily accessible for authorized personnel. Fuses shall be used only where it can be demonstrated that circuit breakers are not practicable. This requirement applies to in-line fuses supplied by either the Contractor or a supplier. Fuse holders shall be constructed to be rugged and waterproof with IP ratings based on TS 34.3 electrical connector installed location requirements. All manual reset circuit breakers critical to the operation of the bus shall be mounted in a location convenient to the Authority's technicians with visible indication of open circuits. The Authority shall consider the application of automatic reset circuit breakers on a case-by-case basis. The Contractor shall show all in-line fuses in the final harness drawings. Any manually resettable circuit breakers shall provide a visible indication of open circuits. Any manually resettable circuit breakers shall provide a visible indication of open circuits.

Circuit breakers or fuses shall be sized to a minimum of 15 percent larger than the total circuit load. The current rating for the wire used for each circuit must exceed the size of the circuit protection being used.

TS 34.2 Grounds

The batteries shall be grounded to the vehicle chassis / frame at one location only, as close to the batteries as possible. When using a chassis ground system, the chassis shall be grounded to the frame in multiple locations, evenly distributed throughout the vehicle to eliminate ground loops. No more than three ground ring / spade terminal connections shall be made per ground stud with spacing between studs ensuring conductivity and serviceability. Electronic equipment requiring an isolated ground to the battery (i.e., electronic ground) shall not be grounded through the chassis.

TS 34.3 Low Voltage / Low Current Wiring and Terminals

All power and ground wiring shall conform to specification requirements of SAE Recommended Practice J1127, J1128 and J1292. Double insulation shall be maintained as close to the junction box, electrical compartment, or terminals as possible. The requirement for double insulation shall be met by wrapping the harness with plastic electrical tape or by sheathing all wires and harnesses with non-conductive, rigid, or flexible conduit.

Wiring shall be grouped, labeled and color-coded. Wiring harnesses shall not contain wires of different voltage classes unless all wires within the harness are insulated for the highest voltage present in the harness. Kinking, grounding at multiple points, stretching, and exceeding minimum bend radius shall be prevented.

Strain-relief fittings shall be provided at all points where wiring enters electrical compartments. Grommets or other protective material shall be installed at points where wiring penetrates metal structures outside of electrical enclosures. Wiring supports shall be protective and non-conductive at areas of wire contact and shall not be damaged by heat, water, solvents, or chafing.

Wiring shall not be located in environmentally exposed locations under the vehicle. Wiring and electrical equipment necessarily located under the vehicle shall be insulated from water, heat, corrosion, and mechanical damage by protective covers. Where feasible, front-to-rear electrical harnesses should be installed above the window line of the vehicle.

All wiring harnesses over 5 ft. long and containing at least five wires shall include 10 percent (minimum one wire) excess wires for spares. This requirement for spare wires does not apply to data links and communication cables. Wiring harness length shall allow end terminals to be replaced twice without pulling, stretching, or replacing the wire. Terminals shall be crimped to the wiring according to the connector manufacturer's recommendations for techniques and tools. All cable connectors shall be locking type, keyed and sealed. Pins shall be removable, crimp contact type, of the correct size and rating for the wire being terminated. Unused pin positions shall be sealed with sealing plugs. Adjacent connectors shall use either different inserts or different insert orientations to prevent incorrect connections.

Terminals shall be crimped, corrosion-resistant and full ring type or interlocking lugs with insulating ferrules. When using pressure type screw terminal strips, only stranded wire shall be used. Insulation clearance shall ensure that wires have a minimum of "visible clearance" and a maximum of two times the conductor diameter or 1/16 in., whichever is less. When using shielded or coaxial cable, upon stripping of the insulation, the metallic braid shall be free from frayed strands that can penetrate the insulation of the inner wires.

Ultrasonic and T-splices may be used with 8 AWG or smaller wire. When a T-splice is used, it shall meet these additional requirements:

1. It shall include a mechanical clamp in addition to solder on the splice.
2. The wire shall support no mechanical load in the area of the splice.
3. The wire shall be supported to prevent flexing.

All splicing shall be staggered in the harness so that no two splices are positioned in the same location within the harness.

Wiring located in any compartment shall be routed away from high-heat sources or shielded and/or insulated from temperatures exceeding the wiring and connector operating requirements.

The instrument panel and wiring shall be easily accessible for service from the driver's seat or top of the panel. The instrument panel shall be separately removable and replaceable without damaging the instrument panel or gauges. Wiring shall have sufficient length and be routed to permit service without stretching or chafing the wires.

Large wires such as battery cables and terminals shall be crimped and soldered with the appropriate connector/terminal end, solder and flux chemistry, according to connector manufacturer's procedures. Soldered wires and cables shall not be stiffened above the terminal, and no flux residue remnants shall be permitted on the terminal.

All wiring connectors outside of junction boxes shall be Deutsch or approved equal, with the terminals coated with dielectric grease. Terminals shall be crimped, corrosion-resistant and full ring type or interlocking lugs, protected with glue type heat shrink.

All *low voltage* electrical connectors shall meet the following minimum requirements:

4. IP 67 for all electrical connectors located outside of junction boxes
5. IP 67 for all electrical connectors located inside the low voltage battery compartment, HVAC compartment, and HVAC ducts
6. IP 65 and IP 69K for all electrical connectors located in areas exposed to the environment such as the undercarriage
7. IP 44 for all electrical connectors located inside sealed compartments or inside junction boxes

TS 34.4 Electrical Components

All electrical components, including switches, relays, flashers, and circuit breakers, shall be heavy-duty designs with either a successful history of application in heavy-duty vehicles or design specifications for an equivalent environment.

All switches located fully inside the bus passenger or operator compartments shall have no less than an IP 63 rating.

All electric motors shall be heavy-duty brushless type where practical, and have a continuous duty rating of no less than 40,000 hours. All electric motors shall be easily accessible for servicing.

TS 34.5 Electrical Compartments

All relays, controllers, flashers, circuit breakers and other electrical components shall be mounted in easily accessible electrical compartments. All compartments exposed to the outside environment shall be corrosion-proof and sealed. The components and their functions in each electrical compartment shall be identified and their location permanently recorded on a drawing attached to the inside of the access panel or door. The drawing shall be protected from oil, grease, fuel, and abrasion.

The front compartment shall be completely serviceable from the driver's seat, vestibule or from the outside. Vehicle run, rear , and Drive Disable controls shall be mounted in an accessible location in the drive unit/motor compartment and shall be protected from the environment.

All junction boxes shall meet the following minimum requirements:

1. IP 64 for all junction boxes located inside sealed compartments
2. IP 66 for all junction boxes not located in sealed compartments
3. IP 65 and IP 69K for all junction boxes located in areas exposed to the environment such as the undercarriage

TS 35. General Electronic Requirements

If an electronic component has an internal real-time clock, it shall provide its own battery backup to monitor time when battery power is disconnected, and/or it may be updated by a network component.

Backup batteries shall be an easily replaceable entity. Replacement of the backup battery shall not require the replacement of any related module or component.

Backup battery manufacturing dates must be within 3 months of bus shipment dates.

If an electronic component has an hour meter, it shall record accumulated service time without relying on battery backup.

All electronic component suppliers shall ensure that their equipment is self-protecting in the event of shorts in the cabling, and also in over-voltage (over 32 VDC on a 24 VDC nominal voltage rating with a maximum of 50 VDC) and reverse polarity conditions. If an electronic component is required to interface with other components, it shall not require external pull-up and/or pull-down resistors. Where this is not possible, the use of a pull-up or pull-down resistor shall be limited as much as possible and easily accessible and labeled.

TS 35.1 Wiring and Terminals

Kinking, chafing, grounding at multiple points, stretching, and reducing the bend radius below the manufacturer's recommended minimum, shall not be permitted.

TS 35.1.1 Discrete I/O (Inputs / Outputs)

All wiring to I/O devices, either at the harness level or individual wires, shall be labeled, stamped, or color-coded in a fashion that allows unique identification at a spacing not exceeding 4 in. Wiring for each

I/O device shall be bundled together. If the I/O terminals are the same voltages, then jumpers may be used to connect the common nodes of each I/O terminal.

TS 35.1.2 Shielding

All wiring that requires shielding shall meet the following minimum requirements. A shield shall be generated by connecting to a ground, which is sourced from a power distribution bus bar or chassis. A shield shall be connected at one location only, typically at one end of the cable. However, certain standards or special requirements, such as SAE J1939 or RF applications, have separate shielding techniques that also shall be used as applicable.

When using shielded or coaxial cable, upon stripping of the insulation, the metallic braid shall be free from frayed strands, which can penetrate the insulation of the inner wires. To prevent the introduction of noise, the shield shall not be connected to the common side of a logic circuit.

TS 35.1.3 Communications

The data network cabling shall be selected and installed according to the selected protocol requirements. The physical layer of all network communication systems shall not be used for any purpose other than communication between the system components, unless provided for in the network specifications.

Communications networks that use power line carriers (e.g., data modulated on a 24V power line) shall meet the most stringent applicable wiring and terminal specifications.

TS 35.1.4 Radio Frequency (RF)

RF components, such as radios, video devices, cameras, global positioning systems (GPS), etc., shall use coaxial cable to carry the signal. All RF systems require special design consideration for losses along the cable. Connectors shall be minimized, since each connector and crimp has a loss that shall attribute to attenuation of the signal. Cabling should allow for the removal of antennas or attached electronics without removing the installed cable between them. If this cannot be done, then a conduit of sufficient size shall be provided for ease of attachment of antenna and cable assembly. The corresponding component vendors shall be consulted for proper application of equipment, including installation of cables.

TS 35.1.5 Audio

Cabling used for microphone level and line level signals shall be 22 AWG minimum with shielded twisted pair. Cabling used for amplifier level signals shall be 18 AWG minimum. Cabling shall adhere to component manufacturer’s requirements.

TS 36. Multiplexing (DRS 24)

TS 36.1 General

The primary purpose of the multiplexing system is control of components necessary to operate the vehicle. This is accomplished by processing information from input devices and controlling output devices through the use of an internal logic program.

Versatility and future expansion shall be provided for by expandable system architecture. The multiplex system shall be capable of accepting new inputs and outputs through the addition of new modules and/or the utilization of existing spare inputs and outputs. All like components in the multiplex system shall be modular and interchangeable with self-diagnostic capabilities. The modules shall be easily accessible for troubleshooting electrical failures and performing system maintenance. Multiplex input / output modules shall use solid-state devices to provide extended service life and individual circuit protection.

Ten percent of the total number of inputs and outputs, or at least one each for each voltage type utilized (12 V, 24 V) at each module location shall be designated as spares.

The Authority shall either have the ability to modify the multiplexing logic or the manufacturer shall be responsible for supporting any changes as required for the actual lifetime of the vehicle at no cost to the Authority.

Any programing updates provided by the manufacturer shall have all changes documented and validated, then submitted to the Authority for review prior to being uploaded to any vehicle.

TS 36.2 System Configuration

Multiplexing may either be distributed or centralized. A distributed system shall process information on multiple control modules within the network. A centralized system shall process the information on a single control module. Either system shall consist of several modules connected to form a control network.

TS 36.2.1 I/O Signals

The input / output for the multiplex system may contain four types of electrical signals: discrete, modulating, analog or serial data.

Discrete signals shall reflect the on / off status of switches, levers, limit switches, lights, etc. Analog signals shall reflect numerical data as represented by a voltage signal (0–12V, 10–24V, etc.) or current signal (4–20 mA). Both types of analog signals shall represent the status of variable devices such as rheostats, potentiometers, temperature probes, etc. Serial data signals shall reflect ASCII or alphanumeric data used in the communication between other on-board components.

VIII. DRIVER PROVISIONS, CONTROLS, AND INSTRUMENTATION

TS 37. Driver's Area Controls

Driver's area controls shall be presented to the Authority for review and approval **(Table 2, D10)**.

TS 37.1 General

In general, when designing the driver's area, SAE J833, "Human Physical Dimensions," shall be used.

Switches and controls shall be divided into basic groups and assigned to specific areas, in conformance with SAE Recommended Practice J680, Revised 2015, "Location and Operation of Instruments and Controls in Motor Truck Cabs," and be essentially within the hand reach envelope described in SAE Recommended Practice J287, "Driver Hand Control Reach."

TS 37.2 Glare

The driver's work area shall be designed to minimize glare to the extent possible. Objects within and adjacent to this area shall be matte black or dark gray in color wherever possible to reduce the reflection of light onto the windshield. The use of polished metal and light-colored surfaces within and adjacent to the driver's area shall be avoided.

TS 37.3 Driver's Area Sunshades

A sunshade shall be provided over the driver's windshield and the driver's side window. The shades shall be capable of being lowered to the midpoint of the driver's window. When deployed, the shades shall be secure, stable, and shall not rattle, sway, or intrude into the driver's field of view due to the motion of the bus or as a result of air movement. Once lowered, the shades shall remain in the lowered position until returned to the stowed position by the driver. Sunshade shall be shaped to minimize light leakage between the visor and windshield pillars to the greatest extent possible. The adjustable roller type shades shall be manufactured by Auto-Motion Shade or approved equal. The shades shall be sized to provide adequate shading for the Operator. The exact size and dimensions shall be determined during the Design Review meetings.

TS 37.4 Driver's Controls

Frequently used controls must be in easily accessible locations. These include the door control, kneel control, windshield wiper / washer controls, ramp control, and vehicle run switch. Any switches and controls necessary for the safe operation of the bus shall be conveniently located and shall provide for ease of operation. They shall be identifiable by shape, touch, and permanent markings. Controls also shall be located so that passengers may not easily tamper with control settings.

Driver's mirror adjustment switch(es) shall be located so that mirrors shall be adjusted by the driver while seated in a normal driving position.

All panel-mounted switches and controls shall be marked with easily read identifiers. Graphic symbols shall conform to SAE Recommended Practice J2402, "Road Vehicles – Symbols for Controls, Indicators, and Tell Tales," where available and applicable. Color of switches and controls shall be dark with contrasting typography or symbols.

Mechanical switches and controls shall be replaceable, and the wiring at these controls shall be serviceable from a convenient location. Driver's area switches, controls, and instruments shall be dust- and water-resistant with a minimum rating of IP 63.

All switches/controls in the driver's controls area shall be mounted in an angled panel steep enough to discourage drivers from using it as a personal storage area for items like food, drinks, personal electronic devices, etc.

TS 37.5 Normal Bus Operation Instrumentation and Controls

The following list identifies bus controls used to operate the bus. These controls are either frequently used or critical to the operation of the bus. They shall be located within easy reach of the operator. The operator shall not be required to stand or turn to view or actuate these controls unless specified otherwise. Appropriate LED backlighting of all bus controls shall be provided.

Systems or components monitored by onboard diagnostics system shall be displayed in clear view of the operator and provide visual and/or audible indicators. The intensity of indicators shall permit easy determination of on/off status in bright sunlight but shall not cause a distraction or visibility problem at night. All indicators shall be illuminated using LED backlighting.

The indicator panel shall be located in the instrument cluster and centered in the driver's dash, within easy view of operators ranging in size from a 5th-percentile female to a 95th-percentile male. All indicators shall have a method of momentarily testing their operation. The audible alarm shall be tamper-resistant and shall have an outlet level between 80 and 83 dBA when measured at the location of the operator's ear.

The Contractor shall provide the necessary equipment, software, and documentation/instruction to permit the Authority to change any annunciator message.

On-board displays visible to the operator shall be limited to indicating the status of those functions described herein that are necessary for the operation of the bus. All other indicators needed for diagnostics and their related interface hardware shall be concealed and protected from unauthorized access. **Table 7** represents instruments and alarms. The intent of the overall physical layout of the indicators shall be in a logical grouping of systems and severity nature of the fault.

Consideration shall be provided for future additions of spare indicators as the capability of onboard diagnostic systems improves. Blank spaces shall contain LEDs.

At a minimum, kneeler, wheelchair ramp, and system shutdown override, switches requires operation protection (switch guard) to prevent accidental switch actuation. Additional switches may require operation protection and shall be reviewed in the design review process.

The information provided in **Table 7** is for reference purposes only. The final layout of the driver area instrumentation, controls, and alarms are subject to Authority review and approval during the design review process. The Contractor shall present a minimum of three (3) proposed layouts for Authority consideration. **(Table 2, D10)**

TABLE 7
Instrumentation, Controls, and Alarms

Device	Description	Location	Function	Visual / Audible
Master run switch	Rotary, four-position detent	Side console	Master control for bus, off, day run, night run and clearance ID lights	
Vehicle start, front	Approved momentary switch	Side console	Activates electric drive system	
Vehicle run, rear	Three-position toggle switch	Rear compartment	Permits activating vehicle system from rear of bus. Switch shall also have normal front run position and off position	Amber light
Drive Disable switch	Approved switch configuration	Motor/Drive Unit	Permits disabling of the drive system and Drive Selector from	

TABLE 7
Instrumentation, Controls, and Alarms

Device	Description	Location	Function	Visual / Audible
		Compartment	the rear of the bus without turning the bus off	
Drive selector	Touch panel switch	Dash left wing	Provides selection of propulsion: forward, reverse and neutral	Drive mode selection
HVAC	Switch or switches to control HVAC	Side console	Permits selection of passenger HVAC: toggle switch - full auto with on/off only	
Driver's ventilation	Rotary, three-position detent	Side console	Permits supplemental ventilation: fan off, low or high	
Defroster fan	Rotary, three-position detent	Dash left wing	Permits defroster: fan off, low, medium or high	
Defroster temperature	Variable position	Dash left wing	Adjusts defroster water flow and temperature	
Windshield wiper	One-variable rotary position operating both wipers	Dash left wing	Variable speed control of left and right windshield wipers	
Windshield washer	Push button	Dash left wing	Activates windshield washers	
Dash panel lights	Rotary rheostat or stepping switch	Dash left wing	Provides adjustment for light intensity in night run position	
Interior lights	Three-position switch	Side console	Selects mode of passenger compartment lighting: off, on, normal	
Front WC ramp enable	Three-position switch[1] with operation protection	Dash right wing	Permits operation of front door ramp and kneel operations	Amber light
Streetside rear door ramp enable	Two-way switch with operator protection	Dash right wing	Actuates the interlock system and provides power and an enable signal to the rear door ramp control panel	Amber light
Kneel enable	Three-position keyed switch1 with operation protection	Dash right wing	Permits ramp and kneel activation	Amber light
Front door ramp	Three-position momentary switch	Right side of steering wheel	Permits deploy and stow of front ramp	Red light
Curbside kneel	Three-position momentary switch	Side console	Permits kneeling function of curbside of vehicle	Audible alert

TABLE 7
Instrumentation, Controls, and Alarms

Device	Description	Location	Function	Visual / Audible
Streetside kneel	Three-position momentary switch	Side console	Permits kneeling function of streetside of vehicle	Audible alert
Silent alarm (hoodlum switch)	Recessed push button, NO and NC contacts momentary	Floor	Activates emergency radio alarm at dispatch and permits covert microphone and/or enables destination sign emergency message	Green light (exterior front and rear) with destination sign
Video system event switch	Momentary on/off momentary switch with plastic guard	Side console	Triggers event equipment, triggers event light on dash aft of G-force, hoodlum switch, covert switch, overt switch	Amber light
Left remote mirror	Four-position toggle type	Side console	Permits two-axis adjustment of left exterior flat and convex mirror	
Right remote mirror	Four-position toggle type	Side console	Permits two-axis adjustment of right exterior flat and convex mirror	
Mirror heater	Switch or temperature activated	Side console	Permits heating of outside mirrors when required	
Passenger door control	Five-position handle type detent or two momentary push buttons	Side console, forward	Permits open / close control of front and rear passenger doors	Red light
Rear door override	Two-position switch in approved location	Side console, forward	Allows driver to override activation of rear door passenger tape switches	
System shutdown override	Momentary switch with operation protection	Side console	Permits driver to override auto system shutdown	
Hazard flashers	Two-position switch	Side console	Activates emergency flashers	Two green lights
Fire suppression	Red push button with protective cover	Dash left wing or dash center	Permits driver to override and manually discharge fire suppression system	Red light on side dash
Mobile data terminal	Mobile data terminal bus operator interface panel	Above left dash wing	Facilitates driver interaction with communication system and master log-on	LCD display with visual status and text messages
Farebox interface	Farebox bus operator interface panel	Near farebox	Facilitates driver interaction with farebox system	LCD display attached to farebox

TABLE 7
Instrumentation, Controls, and Alarms

Device	Description	Location	Function	Visual / Audible
Destination sign interface	Destination sign interface panel	In approved location	Facilitates driver interaction with destination sign system, manual entry	LCD display
Turn signals	Momentary push button (two required) raised from other switches	Left foot panel	Activates left and right turn signals	Two green lights and audible indicator
PA manual	Momentary push button	In approved location	Permits driver to manually activate public address microphone	
Low-profile microphone	Low-profile discrete mounting	Steering column	Permits driver to make announcements with both hands on the wheel and focusing on road conditions	
NVR	Tri-color LED Indicator Light	Driver's side dash	Permits driver to identify status of NVR recording system	Multi-colored per TS Attachment 3 Section 2.13 (A)
High beam	Detented push button	In approved location	Permits driver to toggle between low and high beam	Blue light
Parking brake	Pneumatic PPV	Side console (location to be approved by MBTA)	Permits driver to apply and release parking brake	Red light
Emergency brake release	Pneumatic PPV	Vertical side of the side console or dash center	Permits driver to push and hold to release brakes	
Hill holder	No mechanical switch		Applies brakes to prevent bus from rolling	Automatic activation with audible alarm
Master door / interlock	Multi-pole toggle, detented	Out of operator's reach (behind destination sign)	Permits driver override to disable door and brake / accelerator interlock	Red light
Warning interlocks deactivated	Red indicator light	Dash panel center	Illuminates to warn driver that interlocks have been deactivated	Red light
Alarm acknowledge	Push button momentary	Approved location	Permits driver to acknowledge alarm condition	

TABLE 7
Instrumentation, Controls, and Alarms

Device	Description	Location	Function	Visual / Audible
Low Fuel Indicator	Indicator light	Dash center panel	Low Fuel Indicator illuminates when the diesel fuel level in the tank has reached the minimum required for operation of the diesel auxiliary heater	Amber light
Rear door passenger sensor disable	Multi-pole toggle, detented	In sign compartment or driver's barrier compartment	Permits driver to override rear door passenger sensing system	
Indicator / alarm test button	Momentary switch or programming[1]	Dash center panel	Permits driver to activate test of sentry, indicators and audible alarms	All visuals and audibles
Speedometer	Speedometer, odometer, and diagnostic capability, 5-MPH increments	Dash center panel	Visual indication of speed and distance traveled, accumulated vehicle mileage, fault condition display	Visual
Air pressure gauge	Primary and secondary, 5 psi increments	Dash center panel	Visual indication of primary and secondary air systems	Red light and buzzer
Auxiliary Heater Fault indicator	Indicator light	Dash center panel	Notifies the driver if there is a fault with the auxiliary heater(s)	Amber light
Fire detection	Bus operator display	Property specific or dash center	Indication of fire detection activation by zone / location	Buzzer and red light above driver
Stop Lights indicator	Senses application of service and parking brake as well as brake light function	Dash center	Illuminates each time service or parking brake is applied. Also used to indicate malfunctioning stop lights	Red Indicator with circled S
Door obstruction	Sensing of door obstruction	Dash center	Indication of rear door sensitive edge activation	Red light and buzzer
Door ajar	Door not properly closed	Property specific or dash center	Indication of rear door not properly closed	Buzzer or alarm and red light
Low system air pressure	Sensing low primary and secondary air tank pressure	Dash center	Indication of low air system pressure	Buzzer and red light
Systems coolant	Low coolant indicator may be	Within driver's sight	Detects low coolant condition (required for each isolated	Amber light

TABLE 7
Instrumentation, Controls, and Alarms

Device	Description	Location	Function	Visual / Audible
indicator	supplied as audible alert and visual and/or text message		coolant loop)	
High Voltage Leakage indicator	High voltage isolation sensor	Within driver's sight	Detects possible high voltage potential (positive or negative) in the bus chassis/ground. Detection shall trigger warning lamp illumination and shutdown	Red light
Electric Vehicle Stop indicator	Notifies the driver of a major EV system fault	Within driver's sight	Detects EV system major fault	Red light
HVIL Circuit Break	Notifies the driver of a break in the High Voltage Interlock Loop (HVIL)	Within driver's sight	Detects a break in the High Voltage circuit	Red light
ABS indicator	Detects system status	Dash center	Displays system failure	Amber light
ATC indicator	Notifies the driver when ATC is operating	Dash center	ATC lamp illuminates when ATC is operating to limit wheel spin in slippery conditions	Amber light
HVAC indicator	Detects system status	Dash center	Displays system failure	Amber or red light
Low Voltage Charging System indicator (12/24 V)	Detect low voltage charging system status	Dash center	Detects no charge condition and optionally detects battery high, low, imbalance, no charge condition, and initiates time-delayed shutdown	Red light flashing or solid based on condition
High Voltage charging system indicator (ESS)	Detects ESS charging system status	Dash center	Indicates when bus is connected to off-board charger and ESS is accepting charge	Visual
Active Charge/ Regeneration and Power Consumption	Analog gauge and/or digital display showing charge/ regeneration/ power consumption trend	Dash center	Indication of electric regeneration, charging and power consumption	Analog dial gauge and/or digital display
High Voltage Battery System (ESS) indicator	Realtime indication of high voltage (ESS) State of Charge (SoC)	Dash center	Indicates high voltage (ESS) State of Charge (SoC)	Analog dial gauge and/or digital display
Low ESS	Provides indication	Dash center	Provides different warning light	Visual and

TABLE 7
Instrumentation, Controls, and Alarms

Device	Description	Location	Function	Visual / Audible
Warning	of various levels of low ESS SoC		and audible alarm indications of various levels of low ESS SoC below 20%. Indications of 15% and 10% SoC required	Audible
Charge Enable Switch	Two position switch with guard	Side console	Enables the charging of the ESS	Switch and indicator lamp
Parking Brake Unseat Alarm	Annunciated warning if the operator is not in the seat and the parking brake is released	Dash center	Function and warning indications as required in TS 40.6	Audible annunciation and warning indications
Seatbelt Alarm	Operator seatbelt not in use	Dash center	Detects when operator seatbelt is not in use	Audible alarm and visual indicator on dash
Interlock Alarm	Notifies operator the interlock is engaged	Dash center	Provides an alarm whenever the brake and/or accelerator interlock is activated	Audible alarm and visual indicator on dash

1. Indicate area by drawing. Break up switch control from indicator lights.

TS 37.6 Driver Foot Controls

Accelerator and brake pedals shall be designed for ankle motion. Foot surfaces of the pedals shall be faced with wear-resistant, nonskid, replaceable material.

Driver foot controls including throttle and brake pedals and brake treadle valve, shall be installed with corrosion resistant fasteners and for ease of maintenance. Pedal assembly mounting positions shall not trap moisture and debris. Brake treadle valve replacement shall take no more than 1.75 hours and throttle pedal assembly replacement no more than .5 hour.

TS 37.6.1 Pedal Angle

The vertical angle of the accelerator and brake pedals shall be determined from a horizontal plane regardless of the slope of the cab floor. The accelerator and brake pedals shall be positioned at an angle of 37° to 50° at the point of initiation of contact and extend downward to an angle of 10° to 18° at full throttle.

The location of the brake and accelerator pedals shall be determined by the manufacturer, based on space needs, visibility, lower edge of windshield and vertical H-point.

TS 37.6.2 Pedal Dimensions and Position

The floor-mounted accelerator pedal shall be 10 to 12 in. long and 3 to 4 in. wide. Clearance around the pedal must allow for no interference precluding operation or maintenance activities.

The accelerator and brake pedals shall be positioned such that the spacing between them, measured at the heel of the pedals, is between 1 and 2 in. Both pedals should be located approximately on the same plane coincident to the surface of the pedals.

TS 37.7 Driver Foot Switches

Driver foot switches shall be installed with corrosion resistant fasteners and for ease of maintenance. Foot switches and assembly mounting positions shall not trap moisture and debris. Directional (turn), headlight dimmer, PA, and any other foot operated switch replacement shall take no more than .5 hours.

TS 37.7.1 Floor-Mounted Foot Control Platform

The angle of the turn signal platform shall be determined from a horizontal plane, regardless of the slope of the cab floor. The turn signal platform shall be angled at a minimum of 10° and a maximum of 37°. It shall be located no closer to the seat front than the heel point of the accelerator pedal.

The control switches for the turn signals shall be mounted on an inclined, floor-mounted stainless steel enclosure or metal plate mounted to an incline integrated into the driver's platform, located to the left of the steering column. The location and design of this enclosure shall be such that foot room for the operator is not impeded. The inclined mounting surface shall be skid-resistant. All other switches, including high beam and public address system, shall be in approved locations.

The foot switches shall be UL-listed, heavy-duty type, of a rugged, corrosion-resistant metal construction. The foot switches for the directionals shall be momentary type, while those for the PA system and the high beam shall be latching type. The spacing of the switches shall be such that inadvertent simultaneous deflection of switches is prevented.

A silent alarm switch shall be a floor mounted latching switch, in a location approved by the Authority.

TS 38. Driver's Amenities

Driver's amenities shall be presented to the Authority for review and approval **(Table 2, D10)**.

TS 38.1 Coat Hook

A hook and loop shall be provided to secure the driver's coat.

TS 38.2 Storage Box

An enclosed driver storage area shall be provided with a positive latching door (without lock). The minimum size is 1600 in^3

TS 38.3 Safety Equipment Storage Box

The bus shall be equipped with a safety equipment storage box, located on top of the curbside front wheelwell. The box shall be designed to accommodate at a minimum: a fire extinguisher, safety reflective triangle kit, two Authority provided chock blocks, manual wheelchair ramp hook, and glad hand towing adapters. The box shall be made of steel or aluminum and painted black. The box lid shall be sloped and equipped with non-locking latches of an approved design. Size and location of the safety equipment box shall require Authority approval during the Design Review Process. The contractor shall furnish the 10 pound multi-purpose dry chemical fire extinguisher and the highway safety reflective triangle kit of an approved design and type. The fire extinguisher must be rechargeable and have a minimum rating of 4A, 60 BC. The extinguisher shall be silk screen printed with "Property of the MBTA" in letters approximately 1-inch in height. The two chock blocks shall be provided by the Authority.

TS 39. Windshield Wipers and Washers

TS 39.1 Windshield Wipers

The bus shall be equipped with a windshield wiper for each half of the windshield. At 60 mph, no more than 10 percent of the wiped area shall be lost due to windshield wiper lift. For two-piece windshields,

both wipers shall park along the center edges of the windshield glass. For single-piece windshields, wipers shall park along the bottom edge of the windshield. Windshield wiper motors and mechanisms shall be easily accessible for repairs or service. The fastener that secures the wiper arm to the drive mechanism shall be corrosion-resistant.

Wipers shall be electrically powered.

The wipers shall have dual controls to allow independent control of the left and right wipers.

A variable-speed feature shall be provided to allow adjustment of wiper speed for each side of the windshield between approximately five (5) and twenty-five (25) cycles per minute.

Windshield wiper blade manufacturing dates shall be within three months of bus shipment dates.

TS 39.2 Windshield Washers

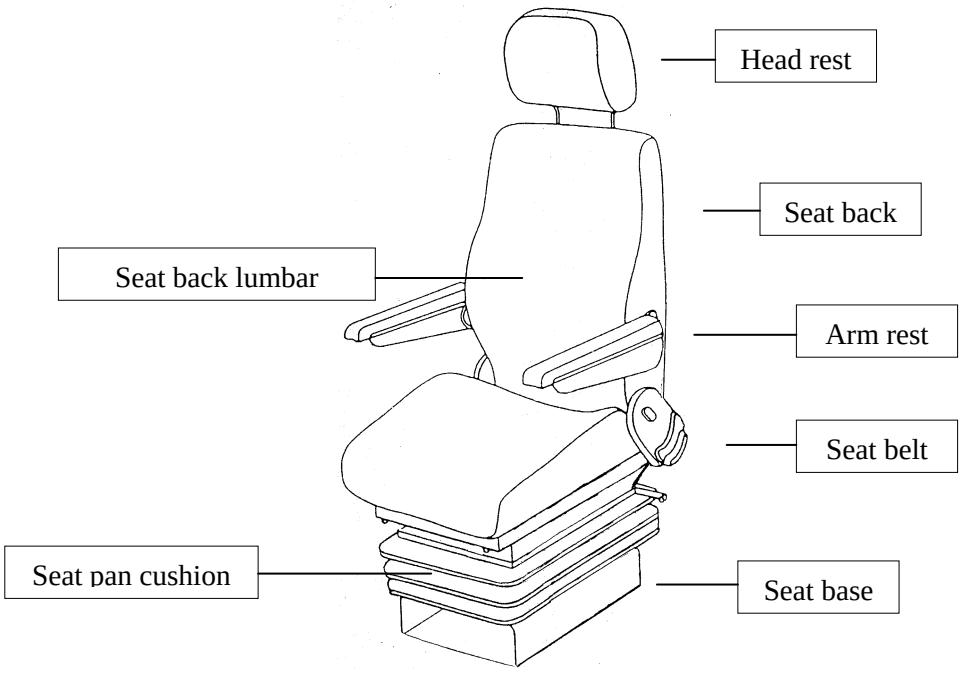
The windshield washer system, when used with the wipers, shall deposit washing fluid evenly on the windshield, and completely wet the entire wiped area.

The windshield washer system shall have a minimum 3-gallon reservoir, located for easy refilling from outside the bus. Reservoir pumps, lines and fittings, shall be corrosion-resistant and must include a means to determine fluid level.

TS 40. Driver's Seat (TABLE 2 D11)

The driver's seat shall be a Recaro Ergo Metro or Authority approved equal. **Figure 3** depicts a generic driver's seat configuration. The exact model shall be determined during the Design Review meetings.

FIGURE 3
Driver's Seat



TS 40.1 Dimensions

The driver's seat shall be comfortable and adjustable so that people ranging in size from a 95th-percentile male to a 5th-percentile female may operate the bus.

TS 40.1.1 Seat Pan Cushion Length

Measurement shall be from the front edge of the seat pan to the rear at its intersection with the seat back. The adjustment of the seat pan length shall be no less than 16.5 in. at its minimum length and no more than 20.5 in. at its maximum length.

TS 40.1.2 Seat Pan Cushion Height

Measurement shall be from the cab floor to the top of the level seat at its center midpoint. The seat shall adjust in height from a minimum of 14 in., with a minimum 6 in. vertical range of adjustment.

TS 40.1.3 Seat Pan Cushion Slope

Measurement is the slope of the plane created by connecting the two high points of the seat, one at the rear of the seat at its intersection with the seat back and the other at the front of the seat just before it waterfalls downward at the edge. The slope can be measured using an inclinometer and shall be stated in degrees of incline relative to the horizontal plane (0°). The seat pan shall adjust in its slope from no less than plus 12° (rearward "bucket seat" incline) to no less than minus 5° (forward slope).

TS 40.1.4 Seat Base Fore / Aft Adjustment

Measurement is the horizontal distance from the heel point to the front edge of the seat. The minimum and maximum distances shall be measured from the front edge of the seat when it is adjusted to its minimum seat pan depth (approximately 15 in.). The seat base shall travel horizontally a minimum of 9 in. It shall adjust no closer to the heel point than 6 in.

TS 40.1.5 Seat Pan Cushion Width

Measurement is the horizontal distance across the seat cushion. The seat pan cushion shall be 17 to 21 in. across at the front edge of the seat cushion and 20 to 23 in. across at the side bolsters.

TS 40.1.6 Seat Suspension

The driver's seat shall be appropriately dampened to support no less than a weight of 380 lbs. The suspension shall be capable of dampening adjustment in both directions**.**

Rubber bumpers shall be provided to prevent metal-to-metal contact.

TS 40.1.7 Seat Back

TS 40.1.7.1 Width

Measurement is the distance between the outermost points of the front of the seat back, at or near its midpoint in height. The seat back width shall be no less than 19 in. Seat back shall include dual recliner gears on both sides of the seat.

TS 40.1.7.2 Height

The driver's seat shall have a standard height seat back.

TS 40.1.8 Headrests

The driver's seat shall have an adjustable headrest.

TS 40.1.9 Seat Back Lumbar Support

Measurement is from the bottom of the seat back at its intersection with the seat pan to the top of the lumbar cushioning. The seat back shall provide adjustable-depth lumbar back support with three individual operating lumbar cells within a minimum range of 7 to 11 in.

TS 40.1.10 Seat Back Angle Adjustment

The seat back angle shall be measured relative to a level seat pan, where 90° is the upright position and 90°-plus represents the amount of recline.

The seat back shall adjust in angle from a minimum of no more than 90° (upright) to at least 105° (reclined), with infinite adjustment in between.

TS 40.2 Seat Belt

The belt assembly shall be an emergency locking retractor (ELR). All seat belts shall be stored in automatic retractors. The belts shall be mounted to the seat frame so that the driver may adjust the seat without resetting the seat belt.

The seat and seatbelt assemblies as installed in the bus shall withstand static horizontal forces as required in FMVSS 207 and 210.

The Contractor shall install a replaceable high visibility safety orange cover over the seatbelt shoulder strap on each bus. The Contractor shall provide one thousand spare covers to the Authority with the delivery of the first serial production bus. The Contractor shall submit replaceable high visibility safety orange shoulder strap covers for Authority review and approval consideration during the design review process.

Seat belts shall be provided across the driver's lap and diagonally across the driver's chest. The three point seat belt assembly shall be adjustable to accommodate drivers ranging in size from a 95th-percentile male to a 5th-percentile female. Three-point seatbelts must be emergency locking retractor (ELR) in design. The upper belt mounting point shall be adjustable for height.

All seatbelt assemblies shall come equipped with a warning switch device (with audible signal) to remind operators to buckle up.

TS 40.2.1 Seat Belt Length

The seat belt assembly shall be 72 in. in length. The Contractor shall provide two separate 8 in. belt extensions of the same color and manufactured for this application by the seat belt OPM, with each delivered bus.

TS 40.3 Adjustable Armrest

Driver's seats shall not be equipped with armrests.

TS 40.4 Seat Control Locations

While seated, the driver shall be able to make seat adjustments by hand without complexity, excessive effort or being pinched. Adjustment mechanisms shall hold the adjustments and shall not be subject to inadvertent changes.

TS 40.5 Seat Structure and Materials

TS 40.5.1 Cushions

Cushions shall be fully padded with at least 3 in. of materials in the seating areas at the bottom and back.

TS 40.5.2 Cushion Materials

Driver's seat foam and fabric shall meet FTA Docket 90A.

TS 40.5.3 Pedestal

Driver's seat pedestal shall be stainless steel.

TS 40.5.4 Additional Seat Requirements

Driver's seat shall be equipped with the following:

1. Occupancy sensor
2. Seatbelt alarm
3. Vinyl boxing
4. Operator adjustable side bolsters
5. Silicone seat cushion (must comply with FTA Docket 90A).

TS 40.6 Seat Alarm

The Contractor shall provide a "parking brake unseat alarm". This safety feature shall be active whether or not the propulsion system is active or the master switch is on or off.

When the operator is not seated with the parking brake released, and ignition/propulsion is either on or off, the following warning shall occur:

1. Instrument cluster audible alarm shall sound
2. Authority approved audible annunciation warning message
    a. The Contractor shall provide the necessary equipment, software, and documentation/instruction to permit the Authority to change the annunciator message
3. Warning message on instrument cluster
4. Kneeler alarm activated
5. Clearance lights flashing
6. Incident to be recorded and transmitted on J-1939 and as per TS Attachment 3 and TS 76.6

TS 40.7 Mirrors

TS 40.7.1 Exterior Mirrors

The bus shall be equipped with corrosion-resistant outside rearview mirrors mounted with stable breakaway mounting system supports to minimize vibration and to prevent loss of adjustment.

The bus shall be equipped with a combination of flat and 6" round (or 5" x 7" rectangular) convex mirrors referred to as transit-specific. The mirrors shall be positioned to prevent blind spots and located so as to provide the driver a view to the rear along both sides of the bus, including the rear wheels, and shall be adjustable both in the horizontal and vertical directions to view the rearward scene. Each flat portion of both street-side and curbside mirrors shall be electronically adjustable from the driver's seat without the operator needing to lean forward from the operating position.

1. Mirror assemblies, including arms, shells, mounts and hardware shall have a corrosion resistant finish.
2. Mirrors shall retract or fold sufficiently to allow bus washing operations but avoid contact with windshield.
3. Both street-side and curbside mirrors shall have integrated turn signals.
4. Both the street-side and curb-side mirrors shall have heaters that energize whenever the driver's heater and/or defroster is activated, or can be activated independently.
5. The streetside and curbside mirrors shall be Hadley or Authority approved equal.

The Contractor shall install left side and right side exterior chassis mirror mounts configured for a potential future retrofit and installation of motorcoach style hang down mirrors. The chassis mirror mounts shall be positioned such that any installed motorcoach mirror shall meet all requirements of 49 CFR 571.111. The chassis mounts shall not be visible on the exterior body panels. The Contractor shall provide chassis drawing showing precise mount locations and retrofit procedures as part of Design Review process.(TABLE 2 D 11)

TS 40.7.1.1 Curbside Mirrors

A high mount mirror is required on the curbside of the bus and shall be positioned so that the driver's line of sight is not obstructed.

TS 40.7.1.2 Street-Side Mirrors

A low mount mirror is required on the street-side of the bus with provisions to accommodate a high mount if desired in the future.

TS 40.7.2 Interior Mirrors

Mirrors shall be provided for the driver to observe passengers throughout the bus without leaving the seat and without shoulder movement. The driver shall be able to observe passengers in the front / entrance and rear / exit areas, anywhere in the aisle, and in the rear seats, utilizing a minimum of four (4) mirrors (rear view, front entrance, front upper right, rear stepwell).

TS 40.7.3 Operator's Auxiliary Fan

An auxiliary fan shall be mounted in the operator's area without obstructing views to provide adjustable airflow for the operator.

IX. WINDOWS

TS 41. Windows

The vehicle window design shall be presented to the Authority for review and approval **(Table 2, D8)**.

TS 41.1 General

A minimum of 10,000 sq. in. of window area, including operator and door windows, shall be required on each side of the standard configuration bus. There shall be no rear window. All glazings shall comply with the requirements of 49 CFR, Chapter V, Part 571.

TS 41.2 Windshield

The Authority prefers a two-piece windshield configuration. The windshield shall permit an operator's field of view as referenced in SAE Recommended Practice J1050. The vertically upward view shall be a minimum of 14°, measured above the horizontal and excluding any shaded band. The vertically downward view shall permit detection of an object 3½ ft high no more than 2 ft in front of the bus. The horizontal view shall be a minimum of 90° above the line of sight. Any binocular obscuration due to a center divider may be ignored when determining the 90° requirement, provided that the divider does not exceed a 3° angle in the operator's field of view. Windshield pillars shall not exceed 10° of binocular obscuration. The windshield shall be designed and installed to minimize external glare as well as reflections from inside the bus.

The windshield shall be easily replaceable by removing zip-locks from the windshield retaining moldings. Bonded-in-place windshields shall not be used. Winglets may be bonded.

TS 41.2.1 Glazing

The windshield glazing material shall have a 1/4 in. nominal thickness laminated safety glass conforming to the requirements of FMVSS 205, ANSI Z26.1 Test Grouping AS-1 and the recommended practices defined in SAE J673.

The upper portion of the windshield above the driver's field of view shall have a dark, shaded band and marked AS-3, with a minimum luminous transmittance of 5 percent when tested in accordance to ASTM D-1003. The band shall be a partial band on the street side of the vehicle only, to allow view for camera and mirror viewing.

TS 41.3 Driver's Side Window

The driver's side window shall be an egress window, and be of a sliding type, requiring only the rear half of the sash to latch upon closing, and shall open sufficiently to permit the seated operator to easily access the street-side outside rearview mirror. When in an open position, the window shall not rattle or close during braking. This window section shall slide in tracks or channels designed to last the service life of the bus. The operator's side window shall not be bonded in place and shall be easily replaceable. The glazing material shall have a single-density tint.

The driver's view, perpendicular through operator's side window glazing, should extend a minimum of 33 in. (840 mm) to the rear of the heel point on the accelerator, and in any case must accommodate a 95th percentile male operator. The view through the glazing at the front of the assembly should begin not more than 26 in. (560 mm) above the operator's floor to ensure visibility of an under-mounted convex mirror. Driver's window construction shall maximize ability for full opening of the window.

The driver's side window glazing material shall have a 1/4 in. nominal thickness laminated safety glass conforming to the requirements of ANSI Z26.1-1996 Test Grouping AS-2 and the recommended practices defined in SAE J673.

The design shall prevent sections from freezing closed in the winter. Light transmittance shall be no less than 70 percent on the glass area below 53 in. from the operator platform floor. On the top-fixed-over-bottom-slider configuration, the top fixed area above 53 in. may have a maximum 5 percent light transmittance.

TS 41.4 Side Windows

TS 41.4.1 Configuration

Side windows shall not be bonded in place, but shall be easily replaceable without disturbing adjacent windows and shall be mounted so that flexing or vibration from propulsion system operation or normal road excitation is not apparent. All aluminum and steel material shall be treated to prevent corrosion.

Each operable side window shall incorporate an upper transom portion. The transom shall be between 25 and 35 percent of the total window area. The lower portion of the window shall be fixed. The transom portion shall be hinged along the lower edge and open inward. This transom portion should be secured with a standard 5/16 in. square key lock.

All passenger side window glazings shall be of a ‘quick change out’ design. Glazing in the window assembly shall be replaced without removing the window from its installed position on the bus or manipulation of the rubber molding surrounding the glazing. The glazing shall be held in place mechanically by a formed metal extruded ring constructed to last the service life of the vehicle. The clamp ring shall be secured in place by stainless steel or hardened corrosion resistant Torx fasteners.

Flush mount windows shall be subject to Authority review and approval.

TS 41.4.2 Emergency Exit (Egress) Configuration

All side windows shall be fixed in position, except as necessary to meet the emergency escape requirements of FMVSS 217. Side window egress systems shall meet all local, state, and federal requirements. Exit windows shall be provided with an emergency exit feature designed for quick resetting by the operator while the vehicle is in service. If the escape device of the windows is top-hinged, it shall be captive (i.e., shall not allow the window to fall out after being pushed open).

Windows shall be traditional frame openable windows with inward-opening transom panels.

TS 41.5 Materials

Side-glazing material shall be 1/4 in. laminated safety glass with no greater than 55 percent light transmittance. Glazing materials shall be in accordance with ANSI Z26.1, latest revision and the recommended practices defined in SAE J673. Sash to be black anodized aluminum. All glazing that is rearward of the yellow standee line shall be equipped with 3M Trans Film 1004, or approved equal, polyester film.

Windows on the bus sides and in the rear door shall be tinted a neutral color, complementary to the bus exterior. The maximum solar energy transmittance shall not exceed 37 percent, as measured by ASTM E424. Luminous transmittance shall be measured by ASTM D1003. Windows over the destination signs shall not be tinted.

Entrance door glazing shall not be less than 70 percent parallel luminous transmittance.

SHGC and light transmission performance shall be defined by the National Fenestration Rating Council.

X. HEATING, VENTILATING AND AIR CONDITIONING

TS 42. Capacity and Performance

The heating, ventilation, and air conditioning (HVAC) climate control system shall be Thermo King or approved equal and shall be capable of controlling and maintaining the interior of the bus at the temperature and humidity levels defined in the following paragraphs.

All aspects of the HVAC system shall be designed, configured, and validated to meet or exceed the HVAC performance requirements of this Technical Specification for buses constructed with streetside and curbside rear door boarding, and front door boarding.

The HVAC unit may either be roof or rear-mounted. Note that the term "roof-mounted unit" includes units mounted on top of, or beneath, the roof surface.

Buses shall be equipped with a fully electric-driven A/C system with full hermetic AC compressor, condenser fan and evaporator blower motors.

The HVAC system shall blend no less than 15% outside fresh air with no more than 85% recycled interior air.

1. Fresh air must be drawn into the HVAC unit through screened weather-protected openings integral to the unit, then shall be filtered and delivered to an integral mixing plenum.
2. HVAC system electronically controlled air blend doors shall control the blend ratio and flow of outside fresh air through the HVAC filters.
3. Return air must pass through the mixing plenum of the HVAC unit where it must mix with the filtered fresh air.
4. The mixture of filtered fresh air and return air must then be filtered.

Methods and components for providing a heat load, whether through a coolant loop and/or auxiliary heater or by an electric grid, shall be of the most energy efficient design so as to minimize ESS consumption when in use.

With the bus running at the design operating profile with corresponding door opening cycle, and carrying a number of passengers equal to the total passenger seating positions (no less than 37), plus the total standees based upon one person for each 1.5 sq. ft. of free floor space, plus the bus driver, the HVAC system shall control the average passenger compartment temperature within a range between 65 and 80 °F, while maintaining the relative humidity to a value of 50 percent or less. The system shall maintain these conditions while subjected to any outside ambient temperatures within a range of 10 to 95 °F and at any ambient relative humidity levels between 5 and 50 percent.

When the bus is operated in outside ambient temperatures of 95 to 115° F, the interior temperature of the bus shall be permitted to rise 0.5° F for each degree of exterior temperature in excess of 95° F.

When the bus is operated in outside ambient temperatures in the range of -10 to 10 °F, the interior temperature of the bus shall not fall below 55 °F while the bus is running on the design operating profile.

System capacity testing, including pull-down / warm-up, stabilization, and profile, shall be conducted in accordance to APTA's Recommended Practice *"Transit Bus HVAC System Instrumentation and Performance Testing."* A complete Climate Room Test, reflecting the specified design, shall be conducted. A report confirming compliance for operation in typical operation shall be submitted to the Authority for review and approval. Testing shall demonstrate that HVAC requirements do not negatively impact the required operating range **(Table 2, D12).**

If prior testing has been performed by the Contractor that documents compliance with the stated performance requirements, appropriate test reports and documentation may be submitted for Authority review and approval. Additional testing shall be performed as necessary to ensure compliance to performance requirements stated herein.

The air conditioning portion of the HVAC system shall be capable of reducing the passenger compartment temperature from 115 to 95° F in less than 20 minutes after vehicle start-up. During the cool-down period, the refrigerant pressure shall not exceed safe high-side pressures, and the condenser discharge air temperature, measured 6 in. from the surface of the coil, shall be less than 45 °F above the condenser inlet air temperature. No simulated solar load shall be used. There shall be no passengers on board, and the doors and windows shall be closed.

The pull-up requirements for the heating system shall be in accordance with Section 11.1 of APTA's *Recommended Practice* "Transit Bus HVAC System Instrumentation and Performance Testing." With ambient temperature at -20° F, and vehicle cold soaked at that temperature, the bus heating system shall warm the interior passenger compartment to an average temperature of 70° F ±2° F within 70 minutes.

The air conditioning system shall meet these performance requirements using R407C.

The air conditioning system shall meet the requirements of EPA Phase 2 regulations.

TS 43. Controls and Temperature Uniformity

The HVAC system excluding the driver's heater / defroster shall be centrally controlled with an advanced electronic / diagnostic control system with provisions for extracting / reading data. The system shall be compliant with J1939 Communication Protocol for receiving and broadcasting of data.

The HVAC system must be able to accommodate Authority programable fixed set-points and sliding scale temperature control set points.

Sliding scale temperature control set-points shall be Authority programable and shall be preset for the cooling mode set point to rise no higher than 78° F, and in heating mode no lower than 66° F. Sliding scale temperature control may be a part of the propulsion system load shed strategy only when the ESS SoC is below 15%.

The climate control system shall be fully automatic and control the interior average temperature to within ±2 °F of specified temperature control set point.

The temperature control set point for the system shall be 72° F.

Interior temperature distribution shall be uniform to the extent practicable to prevent hot and/or cold spots. After stabilization with doors closed, the temperatures between any two points in the passenger compartment in the same vertical plane, and 6 to 72 in. above the floor, shall not vary by more than 5 °F with doors closed. The interior temperatures, measured at the same height above the floor, shall not vary more than ±5 °F from the front to the rear from the average temperature determined in accordance with APTA's "Recommended Instrumentation and Performance Testing for Transit Bus Air Conditioning System." Variations of greater than ±5 °F shall be allowed for limited, localized areas provided that the majority of the measured temperatures fall within the specified requirement.

The Contractor shall install shutoff valves in an appropriate Authority approved locations (Quarter-turn ball valves or Authority approved equal) to facilitate maintenance of defroster / heaters.

The contractor shall provide climate room testing reports that verify the system performs as outlined in the above for Authority review and approval **(CDR 19),** TABLE 2 **D12,** and TS Attachment 2

TS 43.1 Auxiliary Heater

Dual mode Auxiliary Heaters shall be provided capable of heating the bus, and provide ESS preconditioning. The dual mode auxiliary heater shall be configured to operate primarily in electric mode

and supplemented by the diesel system as needed depending on the operating condition of the vehicle, in order to meet the performance criteria. The auxiliary heating system shall be designed to be capable of supplemental bus heating, and simultaneously provide ESS preconditioning and thermal management. The auxiliary heater system shall be equipped with safety devices to prevent over fueling, electrical shock, overheating due to loss of coolant or water pump failure, and operation during conditions of low battery voltage. The auxiliary heater system shall automatically cycle "on" and "off" according to the coolant temperature, HVAC, and ESS demands. No driver input shall be required when the master run switch is turned on.

The auxiliary heater shall have a toggle switch accessible only to bus maintenance personnel to permit disabling the auxiliary heater for maintenance purposes.

To facilitate ESS preconditioning and provide heat with the master run switch in the "off" position, the auxiliary heater system shall be capable of being enabled individually either through a momentary switch or preprogramming of the auxiliary heater system control module. Once activated with the master run switch "off", the auxiliary heater system shall continue to operate and cycle until either the momentary switch is toggled to its downward ("off") position, or the master run switch is turned "on," or the time elapsed exceeds 60 minutes, or the ESS preconditioning mode optimum temperature set point is achieved, at which time this auxiliary heater system mode shall automatically be disabled.

The Authority shall have the ability to disable the diesel portion of the auxiliary heat system by means of a software 'toggle' accessible with Contractor supplied software and diagnostic access. When the diesel portion of the auxiliary heating system is deactivated, the auxiliary heat system software shall automatically and seamlessly switch to full electric mode with no loss of vehicle supplemental heat, ESS preconditioning or thermal management capabilities, and no change to controls and activation. The Contractor shall provide a full description and documentation of the diesel/electric modes and the sole electric mode including the software 'toggle' function. The 'toggle' function shall be verified as part of the Pilot bus FAI.

The auxiliary heater system shall be electronically controlled with appropriate diagnostics for troubleshooting. Operation, as well as diagnostic data, shall be stored and shall be retrievable through a Windows equipped compatible laptop (as specified in TS Attachment 5). The auxiliary heater system maintenance/diagnostic information shall be communicated through the appropriate protocol, SAE J1708 or J1939. **(** TABLE 2 , D12)

TS 43.1.1 Auxiliary Heater Exhaust Emissions

The diesel fired portion of the auxiliary heater system shall be California Air Resource Board (CARB) certified utilizing closed-loop oxygen sensor(s) and meet all applicable emission guidelines and standards. The Contractor shall present an exhaust/emissions compliance strategy as part of the design review process.

TS 43.1.2 Auxiliary Heater Exhaust System

Passengers and pedestrians shall be protected from auxiliary heater system exhaust gases and waste heat. The exhaust pipe location shall prevent exhaust gases and waste heat from igniting nearby combustibles (e.g., bus components, grass, etc.), and discoloring or causing heat deformation to the bus including blistering / damage to paint. The entire exhaust system shall be adequately shielded to prevent heat damage to any bus component. The exhaust outlet shall be designed to minimize rain, snow or water generated from high-pressure washing systems from entering into the exhaust pipe and causing damage to the auxiliary heater.

TS 44. Air Flow

TS 44.1 Passenger Area

The cooling mode of the interior climate control system shall introduce air into the bus at or near the ceiling height at a minimum rate of 25 cubic ft. per minute (cfm) per passenger based on the standard configuration bus carrying a number of passengers equal to the total passenger seating positions (no less than 37), plus the total standees based upon one person for each 1.5 sq. ft. of free floor space, plus the bus driver. Airflow shall be evenly distributed throughout the bus, with air velocity not exceeding 100 ft. per minute on any passenger. The ventilating mode shall provide air at a minimum flow rate of 20 cfm per passenger.

Airflow may be reduced to 15 cfm per passenger (equal to the total passenger seating positions (no less than 37), plus the total standees based upon one person for each 1.5 sq. ft. of free floor space, plus the bus driver) when operating in the heating mode. The fans shall not activate until the heating element has warmed sufficiently to ensure at least 70 °F air outlet temperature. The heating air outlet temperature shall not exceed 120 °F under any normal operating conditions.

All passenger facing air distribution duct panels shall have a safety tether system to protect passengers from loose or falling panels.

The climate control blower motors and fan shall be designed such that their operation complies with the interior noise level requirements.

TS 44.2 Driver's Area

The bus interior climate control system shall deliver at least 100 cfm of air to the driver's area when operating in heating, ventilating, and cooling modes. Adjustable nozzles shall permit variable distribution or shutdown of the airflow. Airflow in the heating mode shall be reduced proportionally to the reduction of airflow into the passenger area. The windshield defroster unit shall meet the requirements of SAE Recommended Practice J382, "Windshield Defrosting Systems Performance Requirements," and shall have the capability of simultaneously providing air to the driver's feet and legs. The defroster or interior climate control system shall maintain visibility through the driver's side window.

TS 44.3 Controls for the Climate Control System (CCS)

The controls for the driver's compartment for heating, ventilation and cooling systems shall be integrated and shall meet the following requirements:

5. The heat / defrost system fan shall be controlled by a separate switch that has an "off" position and at least two positions for speed control. All switches and controls shall preclude the possibility of clothing becoming entangled, and shields shall be provided, if required. An "on/off" switch shall be located to the right of or near the main defroster switch.
6. A manually operated control valve shall control the coolant flow through the heater core.
7. If a cable-operated manual control valve is used, then the cable length shall be kept to a minimum to reduce cable seizing. Heater water control valves shall be "positive" type, closed or open. The method of operating remote valves shall require the concurrence of the Authority's project manager.

TS 44.4 Driver's Compartment Requirements

A separate heating, ventilation and defroster system for the driver's area shall be provided and shall be controlled by the driver. The system shall meet the following requirements:

1. The heater and defroster system shall provide heating for the driver and heated air to completely defrost and defog the windshield, driver's side window, and the front door glasses in all operating conditions. Fan(s) shall be able to draw air from the bus body interior and/or exterior through a

control device and pass it through the heater core to the defroster system and over the driver's feet. A minimum capacity of 100 cfm shall be provided. The driver shall have complete control of the heat and fresh airflow for the driver's area.

2. The defroster supply outlets shall be located at the lower edge of the windshield. These outlets shall be durable and shall be free of sharp edges that can catch clothes during normal daily cleaning. The system shall be such that foreign objects such as coins or tickets cannot fall into the defroster air outlets. Adjustable ball vents or louvers shall be provided at the left of the driver's position to allow direction of air onto the side windows.
3. The driver's compartment ventilation system shall maintain comfortable conditions in the driver's compartment when the driver's safety barrier is in the closed position. The Bus manufacturer shall be required to submit verification of driver's compartment climate control operation conformance as part of the design review process.

A ventilation system shall be provided to ensure driver comfort and shall be capable of providing fresh air in both the foot and head areas. Vents shall be controllable by the driver from the normal driving position. Decals shall be provided, indicating "operating instructions" and "open" and "closed" positions. When closed, vents shall be sealed to prevent the migration of water or air into the bus.

TS 44.5 **Driver's Cooling**

A separate fan unit shall provide 100 cfm of air to the driver's area through directionally adjustable nozzles and an infinitely variable fan control, both of which shall be located above and ahead of the driver.

Air from the evaporator shall be provided to the driver's area through vents located on the dash in front of the driver.

TS 45. Air Filtration

Air shall be filtered before entering the AC system and being discharged into the passenger compartment. Filtration shall be to the maximum MERV rating level possible based upon the manufacturer's system design and the Authority's operating environment, but shall be no less than ASHRAE MERV-9. Air filters shall be easily removable for service and shall be cleanable.

TS 46. Passenger Compartment Air Treatment System

The Contractor shall provide, install, and fully integrate, a ThermoKing *Air Purification Solution* system to include a graphene-enhanced photocatalytic oxidation (GPCO) air purification device and improved filtration. The system shall include a pre-filter, all materials, installation, testing, and systems operation qualification. The Contractor shall also provide full product information documentation include service, maintenance, and operations manuals, schematics, and vehicle interface information. **(TABLE 2 , D12)**

TS 47. Roof Ventilators

Each ventilator shall be easily opened and closed manually. When open with the bus in motion, this ventilator shall provide fresh air inside the bus. The ventilator shall cover an opening area no less than 425 sq. in. and shall be capable of being positioned as a scoop with either the leading or trailing edge open no less than 4 in., or with all four edges raised simultaneously to a height of no less than 3½ in. An escape hatch shall be incorporated into the roof ventilator. Roof ventilator(s) shall be sealed to prevent entry of water when closed.

Two roof ventilators shall be provided in the roof of the bus, one approximately over or just forward of the front axle and the other approximately over the rear axle.

TS 48. HVAC Maintainability

Authority technicians shall have access to full diagnostic capabilities including the ability to view high and low refrigerant pressures, monitor component operation, controls, and voltages/currents, and adjust setpoints, using HVAC system diagnostic software.

Refrigerant charge fittings shall be 3/8" (as opposed to standard 1/4" fittings) to maintain uniformity with the Authority's R407C fleet.

The condenser shall be located to efficiently transfer heat to the atmosphere and shall not ingest air warmed above the ambient temperature by the bus mechanical equipment, or to discharge air into any other system of the bus. The location of the condenser shall preclude its obstruction by wheel splash, road dirt or debris.

HVAC components shall be constructed to resist damage and corrosion. Evaporators and condensers cores shall be constructed of materials designed to resist corrosion throughout the service life of the bus.

TS 49. Entrance / Exit Area Heating

Heat shall be supplied to the entrance and exit areas to maintain a tread surface temperature no less than 35 °F, in an ambient of -10° F, to prevent accumulation of snow, ice or slush with the bus operating under design operating profile and corresponding door opening cycle.

TS 50. Floor-Level Heating

Sufficient floor-level heaters shall be provided to evenly supply heated forced air. All floor level heaters shall have stainless covers secured by corrosion resistant fasteners. Heaters shall be sealed in such a manner as to prevent buildup of water, snow, and/or dirt inside the unit. Any filter shall be easily replaceable in no longer than five minutes. Control of the floor-level heating shall be through the main heating system electronic control.

XI. EXTERIOR PANELS, FINISHES, AND EXTERIOR LIGHTING

TS 51. Design

The bus shall have a clean, smooth, simple design, primarily derived from bus performance requirements and passenger service criteria. The exterior and body features, including grilles and louvers, shall be shaped to facilitate cleaning by automatic bus washers without snagging washer brushes. Water and dirt shall not be retained in or on body features to freeze or bleed out onto the bus after leaving the washer. The body and windows shall be sealed to prevent leaking of air, dust, or water under normal operating conditions and during cleaning in automatic bus washers for the service life of the bus.

Exterior panels shall be sufficiently stiff to minimize vibration, drumming or flexing while the bus is in service. When panels are lapped, the upper and forward panels shall act as a watershed. However, if entry of moisture into the interior of the vehicle is prevented by other means, then rear cap panels may be lapped otherwise. The windows, hatches and doors shall be able to be sealed. Accumulation of spray and splash generated by the bus's wheels shall be minimized on windows and mirrors.

TS 51.1 Materials

Body materials shall be selected, and the body fabricated to reduce maintenance, extend durability, and provide consistency of appearance throughout the service life of the bus. Detailing shall be kept simple, and add-on devices and trim shall be minimized and integrated into the basic design.

Body material surfaces shall be designed and manufactured in such a way as to be protected against graffiti / vandalism.

TS 51.2 Roof-Mounted Equipment

A non-skid, clearly marked walkway or steps shall be incorporated on the roof to provide access to equipment without damaging any system or bus paneling.

TS 51.3 Pedestrian Safety

Exterior protrusions along the side and front of the bus greater than 1/2 in. and within 80 in. of the ground shall have a radius no less than the amount of the protrusion. The exterior rearview mirrors, cameras and required lights and reflectors are exempt from the protrusion requirement. Grilles, doors, bumpers and other features on the sides and rear of the bus shall be designed to minimize toeholds or handholds.

Exterior protrusions shall not cause a line-of-sight blockage for the driver.

The Contractor shall provide an audible pedestrian alert system consistent with the implementation, testing and evaluation standards of 49 CFR 571.141

TS 52. Repair and Replacement

TS 52.1 Side Body Panels

For metallic construction, structural elements supporting exterior body panels shall allow side body panels below the windows to be repaired in lengths not greater than 12.5 ft.

For composite construction with an integral outer skin/body structure, damage shall be confined to the impact area and repairable with common composite repair procedures.

If the bus has lower side body panels made of impact-resistant material, they shall be easily and quickly replaceable. These replaceable panels shall be color impregnated to match the vehicle paint and color scheme.

TS 53. Rain Gutters

Rain gutters shall be provided to prevent water flowing from the roof onto the passenger doors and driver's side window. When the bus is decelerated, the gutters shall not drain onto the windshield,

driver's side window or door boarding area. Cross sections of the gutters shall be adequate for proper operation. Any drain holes in the gutters shall be located between windows.

TS 54. License Plate Provisions

Provisions shall be made to mount standard-size U.S. license plates per SAE J686 on the front and rear of the bus. These provisions shall direct-mount or recess the license plates so that they can be cleaned by automatic bus-washing equipment without being caught by the brushes. The rear license plate provision shall be illuminated per SAE J587. The front license plate shall not be obstructed by any accessory.

The locations of both front and rear license plates shall be proposed by the Contractor and are subject to review and approval by the Authority.

TS 55. Rub Rails

The bus shall not be equipped with rub rails.

TS 56. Fender Skirts

A suitably robust, flexible, low-profile fender skirt shall be incorporated to minimize water spray from the bus in wet condition. Fender skirts shall be easily replaceable. They shall be flexible if they extend beyond the allowable body width. Wheels and tires shall be removable with the fender skirts in place.

TS 57. Splash Aprons

Splash aprons, composed of 1/4 in. minimum composition material or rubberized fabric, shall be installed behind and/or in front of wheels as needed to reduce road splash and to protect underfloor components. The splash aprons shall extend downward to within 3 in. off the road surface at static conditions. Apron widths shall be no less than tire widths. Splash aprons shall be bolted to the bus understructure. Splash aprons and their attachments shall be inherently weaker than the structure to which they are attached. The flexible portions of the splash aprons shall not be included in the road clearance measurements. Splash apron shall be installed as necessary to protect the mobility devices/wheelchair ramp systems from road splash. Other splash aprons shall be installed where necessary to protect bus equipment.

The vehicle shall be equipped with full width front and rear splash aprons.

TS 58. Service Compartments and Access Doors

TS 58.1 Access Doors

Conventional or pantograph hinged doors shall be used for the motor compartment and for all auxiliary equipment compartments, including doors for checking and adding coolant. Access openings shall be sized for easy performance of tasks within the compartment, including tool operating space. Access doors shall be of rugged construction and shall maintain mechanical integrity and function under normal operations throughout the service life of the bus. They shall close flush with the body surface. All doors shall be hinged at the top or on the forward edge and shall be prevented from coming loose or opening during transit service or in bus washing operations. Access doors shall be retained in the open position by props or counterbalancing with over-center or gas-filled springs with safety props and shall be easily operable by one person. Door latches, springs and hinges shall be stainless steel. Latch handles shall be flush with, or recessed behind, the body contour and shall be sized to provide an adequate grip for opening. Access doors, when opened, shall not restrict access for servicing other components or systems. The coolant, windshield washer fluid, and fuel fill access door hinges are spring loaded to hold the door open and closed.

If precluded by design, the manufacturer shall provide door design information specifying how the requirements are met. Proposed door designs are subject to Authority approval during the Design Review Process.

TS 58.2 Access Door Latch / Locks

Access doors larger than 100 sq. in. in area shall be equipped with stainless steel flush-mounted latches or locks of an approved design. All interior and exterior access doors larger than 144 sg. in. in area shall have a secondary latch. All such access doors that require a tool to open shall have the latches standardized throughout the vehicle and shall require a nominal 5/16 in. square male tool to open or lock. The locking mechanism shall have a highly visible alignment indent to be used as visual indication that latches are secured.

All interior and exterior access door latches shall be of a vibration resistant design to prevent unintended opening of access doors.

TS 59. Bumpers

TS 59.1 Location

Bumpers shall provide impact protection for the front and rear of the bus with the top of the bumper being 27 in. (+2, -3 in.), above the ground. Bumper height shall be such that when one bus is parked behind another, a portion of the bumper faces shall contact each other.

TS 59.2 Front Bumper

No part of the bus, including the bumper, shall be damaged as a result of a 5-mph impact of the bus at curb weight with a fixed, flat barrier perpendicular to the bus's longitudinal centerline. The bumper shall return to its pre-impact shape within 10 minutes of the impact. The bumper shall protect the bus from damage as a result of 6.5 mph impacts at any point by the common carriage with contoured impact surface defined in Figure 2 of FMVSS 301 loaded to 4000 lbs. parallel to the longitudinal centerline of the bus. It shall protect the bus from damage as a result of 5.5 mph impacts into the corners at a 30° angle to the longitudinal centerline of the bus. The energy absorption system of the bumper shall be independent of every power system of the bus and shall not require service or maintenance in normal operation during the service life of the bus. The bumper may increase the overall bus length specified by no more than 7 in. with the overall bus length not to exceed 41 feet. (TS 6.1)

The front bumper shall incorporate mounting provisions for an integrated bike rack.

TS 59.3 Rear Bumper

No part of the bus, including the bumper, shall be damaged as a result of a 2-mph impact with a fixed, flat barrier perpendicular to the longitudinal centerline of the bus. The bumper shall return to its pre-impact shape within 10 minutes of the impact. When using a yard tug with a smooth, flat plate bumper 2 ft. wide contacting the horizontal centerline of the rear bumper, the bumper shall provide protection at speeds up to 5 mph, over pavement discontinuities up to 1 in. high, and at accelerations up to 2 mph/sec. The rear bumper shall protect the bus when impacted anywhere along its width by the common carriage with contoured impact surface defined in Figure 2 of FMVSS 301 loaded to 4000 lbs., at 4 mph parallel to or up to a 30° angle to the longitudinal centerline of the bus. The rear bumper shall be shaped to preclude unauthorized riders standing on the bumper. The bumper shall not require service or maintenance in normal operation during the service life of the bus. The bumper may increase the overall bus length specified by no more than 7 in. with the overall bus length not to exceed 41 feet. (TS 6.1)

TS 59.4 Bumper Material

Bumper material shall be corrosion-resistant and withstand repeated impacts of the specified loads without sustaining damage. These bumper qualities shall be sustained throughout the service life of the bus.

TS 60. Finish and Color

TS 60.1 Appearance

All exterior surfaces shall be smooth and free of wrinkles and dents. Exterior surfaces to be painted shall be properly prepared as required by the paint system supplier prior to application of paint to ensure a proper bond between the basic surface and successive coats of original paint for the service life of the bus. Drilled holes and cutouts in exterior surfaces shall be made prior to cleaning, priming, and painting, where possible, to prevent corrosion. The bus shall be painted prior to installation of exterior lights, windows, mirrors, and other items that are applied to the exterior of the bus. Body filler materials may be used for surface dressing, but not for repair of damaged or improperly fitted panels.

Paint system shall be PPG Delfleet Evolution FBCH base coat/clear coat system or Authority approved equal.

In preparation before painting, all exterior surfaces to be painted shall be sanded to a feathered edge, properly cleaned and primed with the appropriate Delfleet FBCH primer, or Authority approved equal. Colored paint and clear coat shall be applied using PPG Delfleet Evolution FBCH, or Authority approved equal. The FBCH base coat/clear coat application shall meet the minimum high gloss, Distinctness of Image (DOI) requirements specified below. Proper adhesion between the basic surface and successive coats of the original paint shall be tested by the Contractor on every 10^{th} bus.

The existing MBTA five color paint codes to be replicated are provided in **Table 8** below for reference.

TABLE 8
Paint Scheme Codes

Color	PPG Paint Code
White	FBCH 947577
Yellow	FBCH 947578
Black	FBCH 947526
Blue	FBCH 947725
Grey	FBCH 947527

Paint shall be applied smoothly and evenly with the finished surface free of visible dirt and the following other imperfections:

1. blisters or bubbles appearing in the topcoat film
2. chips, scratches or gouges of the surface finish
3. cracks in the paint film
4. craters where paint failed to cover due to surface contamination
5. overspray
6. peeling
7. runs or sags from excessive flow and failure to adhere uniformly to the surface
8. chemical stains and water spots
9. dry patches due to incorrect mixing of paint activators
10. buffing swirls

All exterior finished surfaces shall be impervious to diesel fuel, and commercial cleaning agents. Finished surfaces shall resist damage by controlled applications of commonly used graffiti-removing chemicals.

Proper adhesion between the basic surface and successive coats of the original paint shall be measured using an Elcometer adhesion tester as outlined in ASTM D4541-17. The bus manufacturer shall supply test samples of the exterior surface for each step of the painting process that may be subject to adhesion testing per ASTM D4145-10 (2018). Cross hatch adhesion tests per ASTM D3359-17 may be used for inspection testing during assembly of the vehicle. All adhesion tests shall be appropriate for the substrate and shall be performed by trained personnel. There shall be no loss of paint adhesion over the service life of the bus.

Finished painted surfaces shall be high gloss, high DOI, and extremely durable with minimal orange peel effect. All painted surfaces shall have an average minimum 85 gloss rating (at a 20 degree measurement) and an average minimum 80 DOI rating (based on a 0-100 rating system) utilizing Authority approved wave scan / gloss equipment (Altana BYK Wave-Scan 4846 and Micro Gloss 4440 equipment or approved equal). If the body of the bus is divided into different appearance zones (sides, front, rear, and roof), no zone shall have less than an 85 gloss rating. UV, detergents, weathering, and environmental factors shall not result in a loss of 10% paint gloss rating for a minimum of six years. Testing procedures to follow ASTM D523-14 (2018), "Standard Test Method For Specular Gloss" and ASTM D5767-18, "Standard Test Methods for Instrumental Measurement of Distinctness-of-Image Gloss of Coating Surfaces." DOI and paint gloss shall be tested by the Contractor on every 10th bus by trained personnel.

The Contractor shall ensure that all paint color transitions shall be smooth with no visible sharp lines or appearance of raised tape lines.

The bus manufacturer shall submit adhesion testing procedures, life of bus adhesion criteria, DOI and gloss test procedures as part of the design review process.

The vehicle shall be painted with a base coat / clear coat paint system in line with the requirements of TS Attachment 1.

TS 60.2 **Impact Panels**

If the bus has lower skirt panels, they shall be removable impact panels, color impregnated to match the Authority's paint scheme. Except for periodic cleaning, these panels shall be maintenance free, permanently colored and not require refinish / repaint for the service life of the vehicle.

TS 61. Decals, Placards, Numbering and Signing

Monograms, numbers, and other special signing, shall be applied to the inside and outside of the bus as required. Signs shall be durable and fade-, chip-, and peel-resistant. All signage shall be manufactured by Seifert Transit Graphics, or approved equal, and installed per the decal supplier recommendations in Authority approved positions. Installation locations shall be finalized at FAI.

Priority seating signs shall be in compliance with the ADA requirements defined in 49 CFR Part 38, Subpart B, 38.27.

The Contractor shall refer to TS Attachment 1 BEB Graphics Reference Guide for minimum decal and placard requirements.

The Contractor shall provide an appropriate decal for bus fleet roof numbers. The bus numbers shall be sized to appropriately fit on the roof of the bus with minimal distortion. The size and location of the proposed bus fleet roof numbers shall be submitted for review and approval at the Pre-Production Meeting. **(CDR 11)**

TS 61.1 Passenger Information

ADA priority seating signs as required and defined by 49 CFR Part 38, Subpart B, 38.27, shall be provided to identify the seats designated for passengers with disabilities. Refer to TS Attachment 1 for signs/placards.

Requirements for a public information system in accordance with 49 CFR Part 38, Subpart B, 38.35, shall be provided.

TS 62. Exterior Lighting

All exterior lights shall meet the requirements of FMVSS 108. Lamps, lenses, and fixtures shall be designed to prevent entry and accumulation of moisture or dust (minimum of IP 65 rating), and shall be interchangeable to the extent practicable. Two hazard lamps at the rear of the bus shall be visible from behind when the propulsion systems ('engine') service doors are opened. Light lenses shall be designed and located to prevent damage when running the vehicle through an automatic bus washer. Fasteners used to secure lamps shall be stainless steel.

Dialight (or approved equal) LED lamps shall be utilized at all exterior lamp locations.

The bus exterior lighting system shall be configured for DRL (daylight running light) operation.

All LED lamps shall be standard installation of the OEM. The entire assembly shall be specifically coated to protect the light from chemical and abrasion degradation.

LED lamps shall be potted type and designed to last the service life of the bus.

Size of LED lamps used for emergency alarm, tail, brake and turn signal lamps shall be reviewed during the design review process and subjected to Authority approval.

Front marker (clearance) lights as well as lights located on the roof and sides of the bus shall be of the flush mount type to protect the lens against minor impacts.

As a means to facilitate a vehicle inspection, all exterior lights shall illuminate and the backup alarm sound, when the operator simultaneously presses the left and right directional foot switches.

All exterior lighting shall be presented to the Authority for review and approval **(Table 2, D5)**.

TS 62.1 Backup Light / Alarm

Visible and audible warnings shall inform following vehicles or pedestrians of reverse operation. Visible reverse operation warning shall conform to SAE Standard J593. Audible reverse operation warning shall conform to SAE Recommended Practice J994 Type C or D. The backup alarm shall conform to IP 65 and IP 67.

TS 62.2 Doorway Lighting

Lamps at the front and rear passenger doorways shall comply with ADA requirements and shall activate only when the doors open. These lamps shall illuminate the street surface to a level of no less than 1 foot-candle for a distance of 3 feet outward from the outboard edge of the door threshold. The lights may be positioned above or below the lower daylight opening of the windows and shall be shielded to protect passengers' eyes from glare. The doorway lighting design proposals shall be discussed in detail during the design review process.

TS 62.3 Hoodlum Emergency Lights

Four flush rubber mounted sealed green LEDs shall be mounted at the highest practical positions at each corner of the bus for the emergency alarm system. One light shall be mounted on each side of the front destination sign, facing forward. Another pair of rearward facing lights shall be mounted at the upper corners on the rear of the bus. Operation of these lights shall be controlled by the emergency alarm

system described in Section TS 76.2.3, Silent (Emergency) Alarm or when activated by the fire suppression system.

TS 62.4 Turn Signals

Turn-signal lights shall be provided on the front, rear, curb and street sides of the bus. Turn signals shall also be affixed to street side and curb side exterior mirrors. All turn signals and installations shall be in accordance with federal regulations.

TS 62.5 Headlights

Headlamps shall be LED assemblies, configured for DRL (daylight running light) operation, with the application designed for ease of lamp replacement.

Headlamps' design life shall be for the service life of the vehicle, and installation and configuration shall be in accordance with federal regulations.

TS 62.6 Brake Lights

Brake lights shall be provided in accordance with federal regulations.

Bus shall include red, high and center mount brake lamp(s) along the backside of the bus in addition to the lower brake lamps required under FMVSS. The Authority's current configuration consists of two brake lights mounted on the rear center of the bus, with two lights on the left and right (four in total) mounted near the reverse and turn signal lights. The high and center mount brake lamp(s) shall illuminate steadily with brake application. The brake lights design and arrangement shall be reviewed and approved by the Authority during the design review process.

TS 62.7 Service Area Lighting (Interior and Exterior)

LED lamps shall be provided in all compartments where service may be required so as to generally illuminate the area for night emergency repairs or adjustments. These service areas shall include, but not be limited to, the motor/drive unit compartment, the communication box, junction / apparatus panels, and passenger door overhead compartments. Lighting shall be adequate to light the space of the service areas to levels needed to complete typical emergency repairs and adjustments. The service area lamps shall be suitable for the environment in which they are mounted.

Motor/drive unit compartment lamps shall be controlled by a switch mounted near the rear vehicle run controls. All other service area lamps shall be controlled by switches mounted on, or convenient to, the lamp assemblies. Power to the service area lighting shall be programmable. Power shall latch on with activation of the switch and shall be automatically discontinued (timed out) after 30 minutes to prevent damage caused by inadvertently leaving the service area lighting switch in the "on" position.

TS 62.8 External ESS State of Charge Indicator Light

The Contractor shall provide, install, and configure, one single external LED indicator lamp providing ESS state of charge indication. The lamp shall be unobstructed and clearly visible whether approaching the bus from the curbside entrance door or from the front center of the bus. The lamp shall be capable of four color display as required in Table 9 below.

TABLE 9
ESS STATE OF CHARGE INDICATION

ESS State of Charge	LED Lamp Color
80% or greater	Green

50% through 79.9%	Blue
30% through 49.9%	Yellow
Less than 30%	Red
20% and less	Blinking Red

Lamp colors and SoC level lamp indication control logic shall be Authority programmable. The Contractor shall submit their proposed lamp, installation location, demonstrate SoC indication functionality, and lamp programmability, during the design review process.

XII. INTERIOR PANELS AND FINISHES

TS 63. General Requirements

Materials shall be selected on the basis of maintenance, durability, appearance, safety, flammability, and tactile qualities. Materials shall be strong enough to resist everyday abuse, and be vandalism and corrosion resistant. Trim and attachment details shall be kept simple and unobtrusive. Interior trim shall be appropriately secured to avoid resonant vibrations under normal operational conditions.

Interior surfaces more than 10 in. below the lower edge of the side windows or windshield shall be shaped so that objects placed on them fall to the floor when the bus is parked on a level surface. Any components and other electrical components within close proximity to these surfaces shall also be resistant to this cleaning method.

Internal surfaces, as possible, shall be stainless steel or other approved materials.

TS 64. Interior Panels

Panels shall be easily replaceable and tamper resistant. They shall be reinforced, as necessary, to resist vandalism and other rigors of transit bus service. Individual trim panels and parts shall be interchangeable to the extent practicable.

Materials shall comply with the Recommended Fire Safety Practices defined in FTA Docket 90-A, dated October 20, 1993.

Interior panels shall be a combination of textured stainless steel and melamine-type material. Melamine shall be a neutral color complimentary to, and consistent with, the Authority's color scheme The specific interior panel color and configuration shall be proposed by the Contractor and is subject to review and approval by the Authority.**(DRS 13)**

TS 64.1 Driver Partition

A partition or bulkhead between the driver and the street-side front passenger seat shall be provided. If applicable, the electrical cabinet mounted on the streetside front wheelhouse may function as the driver partition. The partition shall minimize glare and reflections in the windshield directly in front of the partition from interior lighting during night operation. The partition shall extend from the floor or wheel housing to the ceiling and shall fit the bus side windows, wall, and ceiling panels to effectively close off the driver's area. Location and shape must permit full seat travel and reclining possibilities that can accommodate the shoulders of a 95th-percentile male. The partition shall have a side return and stanchion to prevent passengers from reaching the driver by standing behind the driver's seat. The lower area between the seat and panel must be accessible to the driver. The partition must be strong enough in conjunction with the entire partition assembly for mounting of such equipment as flare kits, fire extinguishers (1.2 kg), microcomputer, public address amplifier, etc. The partition shall be properly attached to the bus structure to minimize noise and rattles.

The Contractor shall develop and present three driver's partition options for the bus for Authority review, selection, and approval **(CDR 12)**. All options shall be compliant with the conditions listed above.

TS 64.2 Driver's Protection System

Arow Global AROWGUARD Slide Stow Driver Protection System shall be installed unless an Authority approved alternative system is chosen. The Driver's Protection System shall prevent sudden intrusion into the operator's compartment and provide protection to the bus operator in the event of an emergency.

The Driver's Protection System shall meet the following minimum requirements:

1. The barrier shall be securely mounted with specifically located and designed mounting plates

2. The barrier shall accommodate bus operators ranging in size from the 95th percentile male to a 5th percentile female
    a) Required accommodations include ease of ingress and egress to the operator's compartment, ergonomically located and operable latch systems, unobstructed view of curb-side mirrors and the bottom of the entrance door, and unobstructed access to seatbelts
3. The installed barrier assembly shall not exhibit undue noise and vibration during vehicle operation
4. The installation shall allow for verbal communication between the bus operator and passengers
5. All fasteners shall be stainless steel or have a corrosion resistant finish
6. All metallic components shall have an anodized or powder coated finish that complement the bus interior colors
7. The installed barrier shall not restrict access to the farebox for vaulting, service, or bus operator duties
8. Glazing shall be a minimum of 5/16" thick and meet all requirements of FMVSS, SAE, and ANSI standards for automotive glazing including edge finish, anti-glare coating, and markings
    a) The barrier door glazing shall meet the requirements of FMVSS 393.60 (d)
9. The barrier assembly overall design and installation shall allow for easily replaceable components including glazing and latch
10. The barrier assembly with its door closed and secure
11. shall not protrude into the aisle or vestibule beyond the driver's platform and streetside wheel well vertical plane, and impede the use of mobility devices

Conformance to requirements and installation shall be evaluated during the design review process**(CDR 12)**

TS 64.3 Modesty Panels

Sturdy divider panels constructed of durable, unpainted, corrosion-resistant material complementing the interior shall be provided to act as both a physical and visual barrier for seated passengers.

Design and installation of modesty panels located in front of forward-facing seats shall include a handhold or grab handle along its top edge. These dividers shall be mounted on the sidewall and shall project toward the aisle no farther than passenger knee projection in longitudinal seats or the aisle side of the transverse seats. Modesty panels shall extend from at least the window opening of the side windows, and those forward of transverse seats shall extend downward to 2 to 2 ½ in. above the floor. Panels forward of longitudinal seats shall extend to below the level of the seat cushion. Dividers positioned at the doorways, where applicable, shall provide no less than a 2½ in. clearance between the modesty panel and a fully open, inward opening door, or the path of a deploying flip-out ramp to protect passengers from being pinched. Modesty panels installed at doorways shall be equipped with grab rails if passenger assists are not provided by other means.

The modesty panel and its mounting shall withstand a static force of 250 lbs. applied to a 4 × 4 in. area in the center of the panel without permanent visible deformation.

A clear non-glass panel shall be installed from above the modesty panel to the top of the daylight opening and attached to the stanchion.

TS 64.4 Front End

The entire front end of the bus shall be sealed to prevent debris accumulation behind the dash and to prevent the driver's feet from kicking or fouling wiring and other equipment. The front end shall be free of protrusions that are hazardous to passengers standing at the front of the standee line area of the bus during rapid decelerations. Paneling across the front of the bus and any trim around the driver's compartment shall be corrosion resistant formed metal or composite material. All formed metal paneling shall be designed to resist corrosion or deterioration for a period of 14 years or 500,000 miles, whichever comes first. Composite dash panels shall be reinforced as necessary, vandal-resistant, and replaceable. All colored, painted, and plated parts forward of the driver's barrier shall be finished with a surface that reduces glare. Any mounted equipment must have provision to support the weight of equipment.

TS 64.5 Rear Bulkhead

The rear bulkhead and rear interior surfaces shall be manufactured from a material suitable for exterior skin; painted and finished to exterior quality; or paneled with melamine-type material, composite, scratch-resistant plastic or carpeting, and trimmed with stainless steel, aluminum, or composite.

The rear bulkhead paneling shall be contoured to fit the ceiling, side walls and seat backs so that any litter or trash shall tend to fall to the floor or seating surface when the bus is on a level surface. Any air vents in this area shall be louvered to reduce airflow noise and to reduce the probability of trash or liter being thrown or drawn through the grille. If it is necessary to remove the panel to service components located on the rear bulkhead, then the panel shall be hinged or shall be able to be easily removed and replaced. Access points required for adjustment of equipment shall be heavy duty and designed to minimize damage and limit unauthorized access using a standard 5/16 in. square key.

TS 64.6 Headlining

Ceiling panels shall be made of durable, corrosion resistant, easily cleanable material. Headlining shall be supported to prevent buckling, drumming, or flexing and shall be secured without loose edges. Headlining materials shall be treated or insulated to prevent marks due to condensation where panels are in contact with metal members. Moldings and trim strips, as required to make the edges tamperproof, shall be stainless steel, aluminum, or plastic, colored to complement the ceiling material. Headlining panels covering operational equipment that is mounted above the ceiling shall be on hinges for ease of service but retained to prevent inadvertent opening.

TS 64.7 Fastening

Interior panels shall be attached so that there are no exposed unfinished or rough edges or rough surfaces. Fasteners should be corrosion resistant. Panels and fasteners shall not be easily removable by passengers. Exposed interior fasteners should be minimized, and where required shall be tamper resistant.

TS 64.8 Insulation

Any insulation material used between the inner and outer panels shall minimize the entry and/or retention of moisture. Insulation properties shall be unimpaired during the service life of the bus. Any insulation material used inside the motor compartment shall not absorb or retain oils or water and shall be designed to prevent casual damage that may occur during maintenance operations.

The combination of inner and outer panels on the sides, roof, wheel wells and ends of the bus, and any material used between these panels, shall provide a thermal insulation sufficient to meet the interior temperature requirements. The bus body shall be thoroughly sealed so that the driver or passengers cannot feel drafts during normal operations with the passenger doors closed.

All insulation materials shall comply with the Recommended Fire Safety Practices defined in FTA Docket 90-A, dated October 20, 1993.

TS 64.9 Floor Covering

The floor covering shall have a non-skid walking surface that remains effective in all weather conditions, and resistant to bubbling or distorting. The floor covering, as well as transitions of flooring material to the main floor and to the entrance and exit area, shall be smooth and present no tripping hazards. Seams shall be sealed / welded per manufacturer's specifications. The standee line shall be approximately 2 in. wide and shall extend across the bus aisle.

Floor covering and seams shall be a midnight blue or similar. The color and pattern shall be consistent throughout the floor covering. Floor material shall be resistant to shrinkage and have a minimum thickness of 2.25 mm in addition to a maximum weight of 2.4 kg/m^2.

Any areas on the floor that are not intended for standees, such as areas "swept" during passenger door operation and the rear door ramp area ,shall be clearly and permanently marked.

The floor shall be easily cleaned and shall be arranged to minimize debris accumulation.

The flooring shall be installed with no more than one seam and extend from the vertical wall of the rear settee between the aisle sides of transverse seats to the standee line. If the floor is of a bi-level construction, then no more than one single longitudinal seam shall be used on each level. The seam shall be offset to one side so as to limit the exposure to foot and wheelchair traffic. There shall be no seams between the wheel housings. A seamless installation is preferred.

The floor under the seats shall be covered with smooth surface flooring material. The floor covering shall closely fit the sidewall in a fully sealed butt joint or extend to the top of the cove.

As part of the design review process, the Contractor shall submit layout, color and material samples for the Authority's review and approval. **(CDR 13)**

TS 65. Interior Lighting

Passenger compartment lighting shall be LED type. The lighting system shall be designed to last the service life of the bus. The light source shall be located to minimize windshield glare, with distribution of the light focused primarily on the passengers' reading plane while casting sufficient light onto the advertising display. The lighting system may be designed to form part of, or the entire, air distribution duct. Any interior light assembly that is a part of the air distribution duct shall have a safety tether system to protect passengers from loose or falling panels.

The lens material shall be translucent polycarbonate. Lenses shall be designed to effectively "mask" the light source. Lenses shall be sealed to inhibit incursion of dust and insects yet be easily removable for service. Access panels shall be provided to allow servicing of components located behind light panels. If necessary, the entire light fixture shall be hinged.

All interior lighting shall be presented to the Authority for review and approval **(Table 2, D6)**.

TS 65.1 Passenger

The Passenger interior lighting shall be an LED system, operating in the cool white spectrum, and designed to last the service life of the bus.

The first light on each side (behind the driver and the front door) is normally turned on only when the front door is opened with the master run switch is in either the "night run" or "night park" mode. As soon as the door closes, these lights shall go out. These lights shall be turned on at any time if the interior light switch is in the "on" position and the master run switch is any 'on' or 'park' mode.

To further help eliminate windshield reflection/glare on suburban roads where street lighting is at a low level, the second light on the curb side, when the master run switch is in either the "night run" or "night park" mode, shall be off with the interior light switch in the "off" position and on in "normal' position. These lights shall be turned on at any time if the interior light switch is in the "on" position.

LED lighting shall automatically dim when the master run switch is in the 'night run' position and the interior light switch is in the 'normal' position. LED lighting shall be programmable by the Authority to adjust intensity and dimming.

All interior lighting shall be turned off whenever the drive selector is in reverse mode and the master control switch is in any 'run' position.

The specific configuration, design, controls, brightness, and light color, shall require the approval of the Authority. **(Table 2, D6)**.

TS 65.2 Driver's Area

The driver's area shall have a LED light to provide general illumination, and it shall illuminate the half of the steering wheel nearest the driver to a level of 5 to 10 foot-candles.

TS 65.3 Seating Areas

The interior lighting system shall provide a minimum 15 foot-candles illumination on a 1 sq. ft. plane at an angle of 45° from horizontal, centered 33 in. above the floor and 24 in. in front of the seat back at each seat position. Allowable average light level for the rear bench seats shall be 7 foot-candles.

TS 65.4 Vestibules / Doors

Floor surface in the aisles shall be a minimum of 10 foot-candles, and the vestibule area a minimum of 4 foot-candles with the front doors open and a minimum of 2 foot-candles with the front doors closed. The front entrance area and curb lights shall illuminate when the front door is open and master run switch is in the "lights" positions. Rear exit areas and curb lights shall illuminate when the rear doors are open.

TS 65.5 Step Lighting

Step lighting for the intermediate steps between lower and upper floor levels shall be a minimum of 4 foot-candles and shall illuminate in all master run switch positions. The step lighting shall be low profile to minimize tripping and snagging hazards for passengers and shall be shielded as necessary to protect passengers' eyes from glare.

TS 65.6 Ramp Lighting

Exterior and interior ramp lighting at a minimum shall comply with federal regulations. Lamps illuminating the front door and rear door extended mobility device/wheelchair ramps to the street surface shall provide a minimum of 4 foot-candles at the furthest edge of the deployed ramp. The lights may be positioned above or below the lower daylight opening of the windows and shall be shielded to protect passengers' eyes from glare. Lamps shall be positioned to prevent trip hazards due to low visibility as a result of shadows.

TS 65.7 Farebox and Fare Validator Lighting

A light fixture shall be mounted in the ceiling above the farebox and each fare validator location. The fixtures shall be capable of projecting a concentrated beam of light on the farebox and validators. This light shall automatically come on whenever the front and/or rear doors are opened and the master run switch is in the "night run" or "night park" position.

TS 66. Fare Collection

Space and structural provisions shall be made for installation of the Authority's current fare collection devices, which shall be as far forward as practicable. Location of the fare collection device shall not restrict traffic in the vestibule, including passengers who use mobility devices/wheelchairs, and shall allow the driver to easily reach the farebox controls and to view the fare register. The farebox shall not restrict access to the driver area, shall not restrict operation of driver controls, and shall not—either by itself or in combination with stanchions or route destination signs—restrict the driver's field of view per SAE Recommended Practice J1050. The location and mounting of the fare collection device shall allow

use, without restriction, by passengers. The farebox location shall permit accessibility to the vault for easy manual removal or attachment of suction devices. Meters and counters on the farebox shall be readable on a daily basis. The floor under the farebox shall be reinforced as necessary to provide a sturdy mounting platform and to prevent shaking of the farebox.

Contractor shall provide fare collection installation layout to the Authority for approval.

The farebox mounting platform shall be of a sufficient height to allow for servicing of the farebox and farebox wiring. The platform shall be sufficiently robust to support the weight of a fully loaded farebox in the Boston service environment. See also TS 22.3. **(Table 2, D24)**

The Contractor shall procure and fully integrate new Scheidt-Bachman model FB30 fareboxes and all related equipment and harnesses. The Contractor shall provide and install the chassis side farebox harnesses, mounting plates, and straps at the Contractor's factory.

The first pilot bus farebox shall be installed by the Contractor at the Contractor's manufacturing facility.

All production buses shall have farebox installation and validation occurring via MBTA personnel at the local commissioning site prior to Authority acceptance.

TS 66.1 Additional Fare Collection Provisions (AFC 2.0)

In addition to the provisions for the Authority's current fare collection system, the Contractor shall install a Cubic fare validation system in each bus.

Fare validators should be positioned in a manner that is non-intrusive to the riding public and meet all applicable ADA accessibility requirements. The Contractor shall work directly with MBTA's new fare collection system supplier, Cubic Transportation Systems, to determine final fare validator locations and all modifications required to the vehicle. The new fare collection validators shall be located at,

1. One at the entrance door near the farebox
2. Two at each rear doorway with one forward and one aft of the door openings.
3. One centrally located in the mobility device securement area, easily accessible from both securement areas when either neighboring securement area is occupied

A centralized control unit or integration into the existing multiplex system shall be required, in order to provide a 30-minute shutdown timer (sleep mode) after the bus is shut off. Adequate mounting space for the central control unit shall be provided in an easily accessible space with other onboard ITS equipment. Each fare validator requires two sets of 18 AWG twisted-pair wires (for power, ground, ignition sense, and spare) routed from the control unit or multiplex system to each fare validator for when they are installed by Cubic. Stanchion mounting and wiring holes should be drilled in appropriate locations and covered with a semi-permanent cover plate or other appropriate securement method prior to shipment to MBTA. The pre-routed wires shall be clearly marked and terminated with a Deutsch DT style plug with a weatherproof cap.

The new fare collection system shall also require an optimized stanchion design to provide mounting locations for two fare validators at each doorway. All fare validators are to be mounted in a manner that is easily accessible to passengers but does not project into areas that may impede passenger movement. It is the contractor's responsibility to work with Cubic Transportation Systems and the Authority to integrate the fair validator mounting system and submit the design and installation locations for approval.

See TS Attachment 7 for additional specifications on the Fare Collection Validator system. Approval of all fare validator system equipment, fare validator locations, and wiring shall be subject to design review. **(Table 2, D24)**

TS 67. Interior Access Panels and Doors

Access for maintenance and replacement of equipment shall be provided by panels and doors that appear to be an integral part of the interior. Access doors shall be hinged with gas props or over-center springs, where practical, to hold the doors out of the mechanic's way. Panels shall prevent entry of mechanism lubricant into the bus interior. All fasteners that retain access panels shall be captive in the cover.

Access doors shall be secured with locks. The locks shall be standardized so that only one tool is required to open all access doors on the bus.

The locking mechanism shall have a highly visible alignment indent to be used as visual indication that latches are secured.

All interior and exterior access door latches shall be of a vibration resistant design to prevent unintended opening of access doors.

The location and configuration of these panels shall be proposed by the Contractor and is subject to Authority review and approval.

TS 67.1 Floor Panels

Access openings in the floor shall be sealed to prevent entry of fumes and water into the bus interior. Flooring material at or around access openings shall be flush with the floor and shall be edge-bound with stainless steel or another material that is acceptable to the Authority to prevent the edges from coming loose. Access doors and all associated materials, and edge bound trim must be flush mount to prevent tripping hazards. Access openings shall be asymmetrical so that reinstalled flooring shall be properly aligned. Fasteners shall tighten flush with the floor.

The vibration resistant locking mechanism shall have a highly visible alignment indent to be used as visual indication that latches are secured. Floor panel latch design shall prevent an ingress of contaminants and shall prevent latch mechanism corrosion.

The number of special fastener tools required for panel and access door fasteners shall be minimized.

Interior access openings shall be provided in the following locations at a minimum:

1. Drive shaft
2. Shock absorbers (rear)
3. Brakes (rear)
4. Shock absorbers (front)

Note: If the Contractor can demonstrate appropriate maintenance access to a given area, the Authority may waive the requirement for specific access panels.

XIII. PASSENGER ACCOMMODATIONS

TS 68. Passenger Seating

TS 68.1 Arrangements and Seat Style

The passenger seating arrangement in the bus shall be such that seating capacity is maximized and in compliance to the following requirements. As part of the design review process, the Contractor shall prepare a minimum of three proposed seating arrangements for Authority's review and approval **(CDR 13) (Table 2, D9)**. The baseline seating layout defined herein shall be considered the first of the three proposed seating arrangements. These proposals shall include at a minimum: line drawings or renderings; number of seats; number and location of mobility aid and priority seating; number of standees (standees calculated as 1 standee for each 1.5 sg. ft of free floor space) ; estimated curb weight of vehicle; gross load (to be calculated as 200 lbs. for the driver, 600 lbs. for each wheelchair position, and 150 lbs. for each designed passenger seating position and for each 1.5 sq. ft. of free floor space), weight distribution with gross load (axle and wheel loads), and resultant gross vehicle weight.

Maneuvering room inside the bus shall accommodate easy travel for passengers using a mobility device/wheelchair from any ramp, whether front entrance door or rear streetside door, to the securement area.

Passenger seats shall be a slim profile, modern design style, American Seating “Insight” or Authority approved equal. Seats shall be arranged in a transverse, forward-facing configuration, except at the wheel housings, where aisle-facing seats may be arranged as appropriate with due regard for passenger access and comfort. In the lower level, after the securement area, there shall be double forward facing seats on the curb side and single forward facing seats on the street side. In addition, a single flip-up “companion” seat shall be provided on the street side in the forward most position. All flip-up seats shall be equipped with a user friendly locking mechanism that allows the seats to be locked in both the up and down positions.

An appropriate barrier in front of the forward facing seats behind the securement area shall be provided. Barriers shall be configured in such a way to eliminate any gaps greater than 1.5 inches between the side wall and the barrier. The upper area seating shall be optimized for passenger capacity as well as comfort. Base order buses shall accommodate no less than 36 seated passengers. Buses with the streetside boarding configuration option shall accommodate no less than 31 seated passengers.

TS 68.2 Rearward Facing Seats

Rearward facing seats are not allowed.

TS 68.3 Padded Inserts / Cushioned Seats

The passenger seats shall be one-piece molded , un-padded, and non-upholstered, with a colorfast, slip resistant, and cleanable surface.

TS 68.4 Seat Back Configuration

The seat back insert thickness shall not exceed 1 in. in the knee room area.

TS 68.5 Drain Hole in Seats

The seat inserts shall not have provisions for drain holes.

TS 68.6 Hip-to-Knee Room

Hip-to-knee room measured from the center of the seating position, from the front of one seat back horizontally across the highest part of the seat to a vertical surface immediately in front, shall be a minimum of 26 in. At all seating positions in paired transverse seats immediately behind other seating

positions, hip-to-knee room shall be no less than 27 in. To the extent possible seats shall be uniformly spaced to standardize hip-to-knee room.

TS 68.7 Foot Room

Foot room, measured at the floor forward from a point vertically below the front of the seat cushion, shall be no less than 14 in. Seats immediately behind the wheel housings and modesty panels shall limit any potential for reduced foot room.

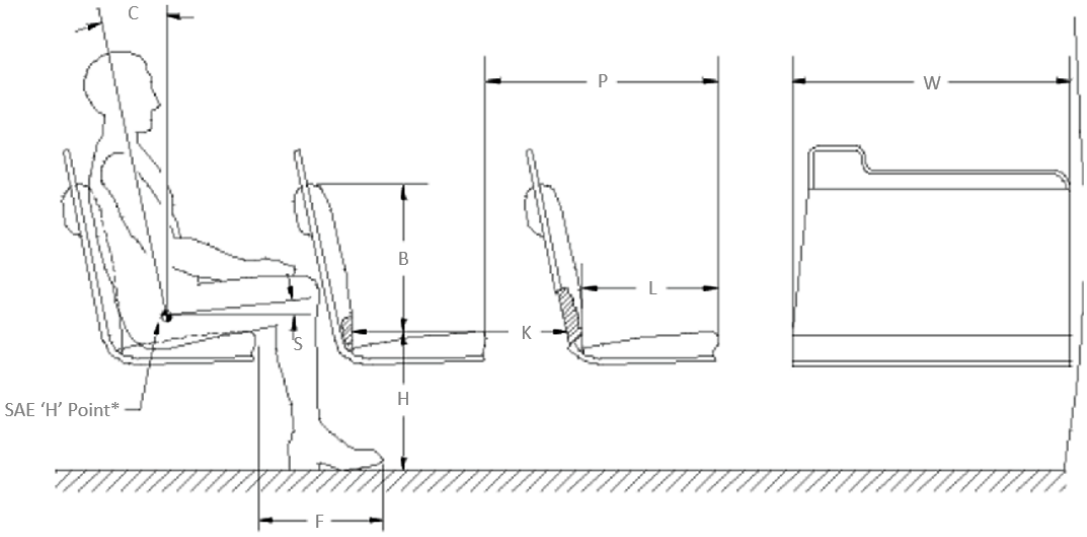
TS 68.8 Aisles

The aisle between the seats shall be no less than 24 in. wide at seated passenger hip height. Seat backs shall be shaped to increase this dimension to no less than 26 in. at 32 in. above the floor (standing passenger hip height).

For buses configured with streetside boarding, aisles from the streetside rear door to the mobility device securement area shall be on less than 34 inches between fixed objects and shall adhere to the requirements of TS 71.3

TS 68.9 Dimensions

FIGURE 4
Seating Dimensions and Standard Configuration



Seat dimensions for the passenger seating arrangement shall have the following dimensions (refer to **Figure 4**):

- The width, W, of the two-passenger transverse seat shall be a minimum 36 in.
- The length, L, shall be 17 in., ±1 in.
- The seat back height, B, shall be a minimum of 16 ½ in.
- The seat height, H, shall be 17 in., ± 1 in. for the rear lounge (or settee) and longitudinal seats, and seats located above raised areas for storage of under-floor components, a height of up to 18 in., ±2 in., shall be allowed. This shall also be allowed for limited transverse seats, but only with the expressed approval of the Authority.
- Foot room = F.

- The seat cushion slope, S, shall be between 5 and 11 deg.
- The seat back slope, C, shall be between 8 and 17 deg.
- Hip to knee room = K.
- The pitch, P, is shown as reference only.

TS 68.10 Structure and Design

The passenger seat frame and its supporting structure shall be constructed and mounted so that space under the seat is maximized and is completely free of obstructions to facilitate cleaning.

Seats, structures, and restraints around the securement area should not infringe into the mobility device envelope or maneuverability.

The transverse seat structure shall be fully cantilevered from the sidewall with sufficient strength for the intended service. The lowest part of the seat assembly that is within 12 in. of the aisle shall be at least 10 in. above the floor.

In locations at which cantilevered installation is precluded by design and/or structure, other seat mounting methods may be allowed.

All transverse objects—including seat backs, modesty panels, and longitudinal seats—in front of forward-facing seats shall not impart a compressive load in excess of 1000 lbs onto the femur of passengers ranging in size from a 5th-percentile female to a 95th-percentile male during a 10 g deceleration of the bus. This deceleration shall peak at 0.05 to 0.015 seconds from initiation. Permanent deformation of the seat resulting from two 95th-percentile males striking the seat back during this 10 g deceleration shall not exceed 2 in., measured at the aisle side of the seat frame at height H. The seat back should not deflect more than 14 in., measured at the top of the seat back, in a controlled manner to minimize passenger injury. Structural failure of any part of the seat or sidewall shall not introduce a laceration hazard.

The seat assembly shall withstand static vertical forces of 500 lbs. applied to the top of the seat cushion in each seating position with less than 1/4 in. permanent deformation in the seat or its mountings. The seat assembly shall withstand static horizontal forces of 500 lbs. evenly distributed along the top of the seat back with less than 1/4 in. permanent deformation in the seat or its mountings. The seat backs at the aisle position and at the window position shall withstand repeated impacts of two 40-lb. sandbags without visible deterioration. One sandbag shall strike the front 40,000 times and the other sandbag shall strike the rear 40,000 times. Each sandbag shall be suspended on a 36 in. pendulum and shall strike the seat back 10,000 times each from distances of 6, 8, 10 and 12 in. Seats at both seating positions shall withstand 4000 vertical drops of a 40-lb. sandbag without visible deterioration. The sandbag shall be dropped 1000 times each from heights of 6, 8, 10 and 12 in. Seat cushions shall withstand 100,000 randomly positioned 3½ in. drops of a squirming, 150-lb., smooth-surfaced, buttocks-shaped striker with only minimal wear on the seat covering and no failures to seat structure or cushion suspension components.

The back of each transverse seat shall incorporate a high contrast handhold no less than 7/8 in. in diameter for standees and seat access / egress. The handhold shall not be a safety hazard during severe decelerations. The handhold shall extend above the seat back near the aisle so that standees shall have a convenient vertical assist, no less than 4 in. long that may be grasped with the full hand. This handhold shall not cause a standee using this assist to interfere with a seated 50th-percentile male passenger. The handhold shall also be usable by a 5th-percentile female, as well as by larger passengers, to assist with seat access / egress for either transverse seating position. The upper rear portion of the seat back and the seat back handhold immediately forward of transverse seats shall be padded and/or constructed of energy-absorbing materials. During a 10 g deceleration of the bus, the Head Injury Criterion (HIC) number (as defined by SAE Standard J211a) shall not exceed 400 for passengers ranging in size from a 5th percentile female through a 95th percentile male.

The seat back handhold may be deleted from seats that do not have another transverse seat directly behind and where a vertical assist is provided.

Longitudinal seats shall be the same general design as transverse seats but without seat back handholds. Longitudinal seats may be mounted on the wheelhouses. Armrests shall be included on the ends of each set of longitudinal seats except on the forward end of a seat set that is immediately to the rear of a transverse seat, the driver's barrier, or a modesty panel, when these fixtures perform the function of restraining passengers from sliding forward off the seat. Armrests are not required on longitudinal seats located in the mobility device/wheelchair securement areas that fold up when the armrest on the adjacent fixed longitudinal seat is within 3½ in. of the end of the seat cushion. Armrests shall be located from 7 to 9 in. above the seat cushion surface. The area between the armrest and the seat cushion shall be closed by a barrier or panel. The top and sides of the armrests shall have a minimum width of 1 in. and shall be free from sharp protrusions that form a safety hazard.

Seat back handhold and armrests shall withstand static horizontal and vertical forces of 250 lbs. applied anywhere along their length with less than 1/4 in. permanent deformation. Seat back handhold and armrests shall withstand 25,000 impacts in each direction of a horizontal force of 125 lbs. with less than 1/4 in. permanent deformation and without visible deterioration.

The Authority reserves the right to require the Contractor to perform all testing required to validate their compliance with all performance requirements of TS 68.10 .

TS 69. Passenger Assists

Passenger assists in the form of full grip, vertical stanchions or handholds shall be provided for the safety of standees and for ingress / egress. Passenger assists shall be convenient in location, shape and size for both a 95th-percentile male and the 5th-percentile female standee. Starting from the entrance door and moving anywhere in the bus and out the exit door, a vertical assist shall be provided either as the vertical portion of the seat back assist or as a separate item so that a 5th-percentile female passenger may easily move from one assist to another using one hand and then the other without losing support.

All stanchions shall be properly secured/staked in a manner as approved by the Authority and be a high-contrast powder-coated yellow.

Stanchions shall be designed and configured for mounting of fare validators per locations identified in TS 66.1

The Contractor shall submit the color scheme and drawings for all stanchions, grab rails, and passenger assist straps for Authority review and approval during the design review process.

TS 69.1 Assists

Excluding those mounted on the seats and doors, the assists shall have a cross-sectional diameter between 1¼ and 1½ in. or shall provide an equivalent gripping surface with no corner radii less than 1/4 in. All passenger assists shall permit a full hand grip with no less than 1½ in. of knuckle clearance around the assist. Passenger assists shall be designed to minimize catching or snagging of clothes or personal items and shall be capable of passing the NHTSA Drawstring Test.

Any joints in the assist structure shall be underneath supporting brackets and securely fastened to prevent passengers from moving or twisting the assists. Seat handholds may be of the same construction and finish as the seat frame. Door-mounted passenger assists shall be of anodized aluminum, stainless steel, or powder-coated metal. Connecting tees and angles may be powder-coated metal castings. Assists shall withstand a force of 300 lbs. applied over a 12 in. lineal dimension in any direction normal to the assist without permanent visible deformation. All passenger assist components, including brackets, clamps, screw heads and other fasteners used on the passenger assists shall be designed to eliminate pinching, snagging, and cutting hazards and shall be free from burrs or rough edges.

TS 69.2 Front Doorway

Front doors, or the entry area, shall be fitted with ADA-compliant assists. Assists shall be as far outward as practicable, but shall be located no farther inboard than 6 in. from the outside edge of the entrance step and shall be easily grasped by a 5th-percentile female boarding from street level. Door assists shall be functionally continuous with the horizontal front passenger assist, the vertical assist, and the assists on the wheel housing or on the front modesty panel.

TS 69.3 Vestibule

The aisle side of the driver's barrier, the wheel housings, and when applicable the modesty panels, shall be fitted with vertical passenger assists that are functionally continuous with the overhead assist and that extend to within 36 in. of the floor. These assists shall have sufficient clearance from the barrier to prevent inadvertent wedging of a passenger's arm.

A horizontal passenger assist shall be located across the front of the bus and shall prevent passengers from sustaining injuries on the fare collection device or windshield in the event of a sudden deceleration. Without restricting the vestibule space, the assist shall provide support for a boarding passenger from the front door through the fare collection procedure. The assist shall be no less than 36 in. above the floor. The assists at the front of the bus shall be arranged to permit a 5th-percentile female passenger to easily reach from the door assist to the front assist, then to vertical assists on the driver's barrier, wheel housings, or front modesty panel.

TS 69.4 Rear Doorway (s)

Rear doors or the entry area, shall be fitted with ADA-compliant assists. Vertical assists that are functionally continuous with the overhead assist shall be provided at the aisle side of the transverse seat immediately forward of the rear doors and on the aisle side of the rear door modesty panels. Passenger assists shall be provided on modesty panels that are functionally continuous with the rear door assists. Rear doors, or the exit areas, shall be fitted with assists having a cross-sectional diameter between 1¼ and 1½ in. or providing an equivalent gripping surface with no corner radii less than 1/4 in., and shall provide at least 1½ in. of knuckle clearance between the assists and their mounting. Assists shall be as far outward as practicable, but shall be located no farther inboard than 6 in. from the outside edge of the rear doorway step and shall be easily grasped by a by a 5th-percentile female boarding from street level. Assists shall be designed to permit a 5th-percentile female to easily move from one assist to another during the entire entering/exiting process.

TS 69.5 Overhead

Except forward of the standee line and at the rear doors, a continuous, full-grip, overhead assist shall be provided. This assist shall be located over the center of the aisle seating position of the transverse seats. The assist shall be no less than 70 in. above the floor.

Grab straps or other extensions as necessary shall be provided for sections where vertical assists are not available and for use by passengers that cannot reach to 70 in.

Grab straps shall be made of an antimicrobial and non-absorbent material such as plastic with a metal split retaining collar, meet docket 90-A requirements, .and individually support the weight of a 95th-percentile male passenger.

Overhead assists shall simultaneously support the weight of a 95th-percentile male passenger on any 12 in. length. No more than 5 percent of the full grip feature shall be lost due to assist supports.

TS 69.6 Longitudinal Seat Assists

Longitudinal seats shall have vertical assists located between every other designated seating position, except for seats that fold / flip up to accommodate mobility device/wheelchair securement. Assists shall extend from near the leading edge of the seat and shall be functionally continuous with the overhead

assist. Assists shall be staggered across the aisle from each other where practicable and shall be no more than 52 in. apart or functionally continuous for a 5th percentile female passenger.

TS 69.7 Wheel Housing Barriers / Assists

Unless passenger seating is provided on top of wheel housings, passenger assists shall be mounted around the exposed sides of the wheel housings (and propulsion compartments if applicable), which shall also be designed to prevent passengers from sitting on wheel housings. Such passenger assists shall also effectively retain items, such as bags and luggage, placed on top of wheel housings.

TS 70. Passenger Doors

Doorways shall be provided in the locations and styles as follows. Passenger doors and doorways shall comply with ADA requirements.

Passenger doors shall be pneumatically actuated Vapor Slide Glide, or Authority approved equal.

TS 70.1 Front door

The front door shall be forward of the front wheels and under direct observation of the driver.

TS 70.2 Rear Doors

Base order buses shall be equipped with curbside rear doors. Streetside Boarding Option buses shall have streetside and curbside rear doors of the same size and configuration with standardized componentry for ease of maintenance.

The rear doorway centerline shall be located rearward of the point midway between the front door centerline and the rearmost seat back.

TS 70.3 Materials and Construction

Structure of the doors, their attachments, inside and outside trim panels and any mechanism exposed to the elements shall be corrosion resistant. Door panel construction shall be of corrosion-resistant metal or reinforced non-metallic composite materials. When fully opened, the doors shall provide a firm support and shall not be damaged if used as an assist by passengers during ingress or egress. Door edges shall be sealed to prevent infiltration of exterior moisture, noise, dirt, and air elements from entering the passenger compartment, to the maximum extent possible based on door types.

The closing edge of each door panel shall have no less than 2 in. of soft weather stripping. The doors, when closed, shall be effectively sealed, and the hard surfaces of the doors shall be at least 4 in. apart (not applicable to single doors). The combined weather seal and window glazing elements of the front door shall not exceed 10° of binocular obstruction of the driver’s view through the closed door.

TS 70.4 Dimensions

FIGURE 5
Door Opening Dimensions

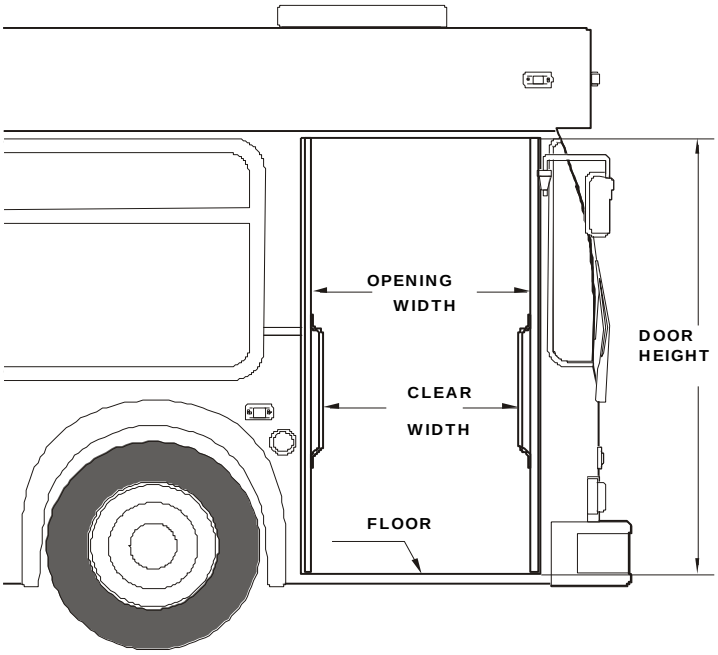


Figure 5 identifies door opening dimension nomenclature.

When open, all doors shall leave an opening no less than 75 in. in height.

The front door *clear width* shall be a minimum of 34 in. with the doors fully opened. The rear door *clear width* shall be a minimum of 36 in. with the doors fully opened.

TS 70.5 Door Glazing

The upper section of both front and rear doors shall be glazed for no less than 45 percent of the respective door opening area of each section. The lower section of the front door shall be glazed for no less than 25 percent of the door opening area of the section. The lower section of the rear door shall not be glazed.

Both the front and rear door glazing shall be easily replaceable, with full exterior glass quick change glazing with hidden frame (tempered glass only).

The front door panel glazing material shall have a nominal 1/4 in. thick tempered glass conforming with the requirements of ANSI Z26.1 Test Grouping 2 and the recommended practices defined in SAE J673.

TS 70.6 Door Projection

TS 70.6.1 Exterior

The exterior projection of the front doors beyond the side of the bus shall be minimized and shall not block the line of sight of the rear curb side exit doors via the curb side mirror when the doors are fully open. The exterior projection of front and rear doors shall be minimized and shall not exceed 14 in. during the opening or closing cycles or when doors are fully opened

TS 70.6.2 Interior

Door projection inside the bus shall not cause an obstruction of the rear door mirror or cause a hazard for standees.

TS 70.7 Door Height Above Pavement

It shall be possible to open and close any passenger door when the bus, loaded to gross vehicle weight rating, is not knelt and parked with the tires touching an 8 in. high curb on a street sloping toward the curb so that the street-side wheels are 5 in. higher than the right-side wheels.

TS 70.8 Closing Force

Closing door edge speed shall not exceed 12 in. per second, and opening door speed shall not exceed 19 in. per second. Power doors shall not slam closed under any circumstance, even if the door is obstructed during the closing cycle. If a door is obstructed during the closing cycle, the pressure exerted on the obstruction shall not increase once initial contact has been made.

Doors closed by a return spring or counterweight-type device shall be equipped with an obstruction-sensing device that, at a minimum, alerts the driver if an obstruction is detected between the closing doors. Doors closed by a return spring or counterweight type device, when unlocked, shall be capable of being pushed to the point where the door starts to open with a force not to exceed 25 lbs. applied to the center edge of the forward door panel.

Whether or not the obstruction-sensing system is present or functional, it shall be possible to withdraw a 1½ in. diameter cylinder from between the center edges of a closed and locked door with an outward force not greater than 35 lbs.

TS 70.8.1 Rear Door Closing Force

Power-close rear doors shall be equipped with an obstruction-sensing system such that if an obstruction is within the path of the closing doors, the doors shall stop and/or reverse direction prior to imparting a 10-lb. force on 1 sq. in. of that obstruction. If a contactless obstruction sensing system is employed, it shall be capable of discriminating between the normal doorway environment and passengers or other obstructions within the doorway, and of altering the zones of detection based upon the operating state of the door system.

TS 70.9 Actuators

The door system shall be air powered.

Doors shall open or close completely in not more than 3.5 seconds from the time of control actuation and shall be subject to the closing force requirements.

Door actuators shall be adjustable so that the door opening and closing speeds can be independently adjustable to satisfy the above requirements. Actuators and the complex door mechanism shall be concealed from passengers but shall be easily accessible for servicing. The door actuators shall be rebuildable.

Door actuators and associated linkages shall maximize door holding forces in the fully open and fully closed positions to provide firm, non-rattling, non-fluttering door panels while minimizing the force exerted by the doors on an obstruction midway between the fully open and closed positions.

The rear door actuator(s) shall be under the complete control of the vehicle operator and shall open and close in response to the position of the driver’s door control.

Doors that employ a “swing” or pantograph geometry and/or are closed by a return spring or counterweight-type device shall be equipped with a positive mechanical holding device that automatically engages and prevents the actuation mechanism from being back-driven from the fully closed position.

The holding device shall be overcome only when the driver's door control is moved to an "Exit Door Enable" position and the vehicle is moving at a speed of less than 2 mph, or in the event of actuation of the emergency door release.

Locked doors shall require a force of more than 300 lbs. to open manually. When the locked doors are manually forced to open, damage shall be limited to the bending of minor door linkage with no resulting damage to the doors, actuators, or complex mechanism.

TS 70.10 Emergency Operation

In the event of an emergency, it shall be possible to manually open doors designated as emergency exits from inside the bus using a force of no more than 25 lbs. after actuating an unlocking device.

The unlocking device shall be clearly marked as an emergency-only device and shall require two distinct actions to actuate. The respective door emergency unlocking device shall be accessible from the doorway area. The unlocking device shall be easily reset by the operator without special tools or opening the door mechanism enclosure. Service access shall utilize a ¼-turn butterfly latch. Doors that are required to be classified as "emergency exits" shall meet the requirements of FMVSS 217.

TS 70.11 Door Control

The door control shall be located in the operator's area within the hand reach envelope described in SAE Recommended Practice J287, "Driver Hand Control Reach." The driver's door control shall provide tactile feedback to indicate commanded door position and resist inadvertent door actuation.

The door control shall be located on the street side of the vehicle in a location to be approved by the Authority.

The front door shall remain in its commanded state / position even if power is removed or lost.

TS 70.12 Door Controller

The control device shall be protected from moisture. Mounting and location of the door control device handle shall be designed so that it is within comfortable, easy arm's reach of the seated driver. The door control device handle shall be free from interference by other equipment and have adequate clearance so as not to create a pinching hazard.

Position of the door control handle shall result in the following operation of the front and rear doors:

1. **Center position**: Front door closed, rear door(s) closed or set to lock.
2. **First position forward**: Front door open, rear door(s) closed or set to lock.
3. **Second position forward:** Front door open, curbside rear door(s) open or set to open.
4. **First position back:** Front door closed, curbside rear door(s) open or set to open.
5. **Second position back:** Front door closed, streetside rear door(s) open or set to open.

TS 70.13 Door Open / Close

Operation of, and power to, the passenger doors shall be completely controlled by the operator.

A control or valve in the operator's compartment shall shut off the power to, and/or dump the power from, the front door mechanism to permit manual operation of the front door with the bus shut down. A master door switch, which is not within reach of the seated operator, when set in the "off" position shall close the rear doors, deactivate the door control system, release the interlocks, and permit only manual operation of the rear doors.

TS 71. Accessibility Provisions

TS 71.1 ADA Compliant Ramp System

Base order buses shall be equipped with an ADA compliant ramp system at the front entrance door. Buses with streetside boarding option shall be equipped with ADA compliant ramp systems at the front entrance door and the streetside door.

Front door and streetside exit door ramp systems shall be of the same size and configuration with standardized componentry for ease of maintenance.

Automatically controlled, power-operated ramp systems compliant to requirements defined in 49 CFR Part 38, Subpart B, §38.23c shall provide ingress and egress quickly, safely, and comfortably, both in forward and rearward directions, for passengers who use wheeled mobility devices boarding and disembarking from a level street or curb.

The ramp systems shall be of a simple hinged, flip-out type design being capable of deploying to the ground at a 1:6 slope or better. The ramp shall have minimal grade transitions that shall allow all 4 wheels of a mobility device to remain in contact with the bus at all times. When the ramp is in the deployed position, the ramp's inboard surface (adjacent the aisle) shall transition upward to provide a level boarding surface for easier passenger progression to and from the designated securement area.

The ramp shall be self-contained unit having all the drive system components located within the interior of the ramp assembly and shall include easy access from the interior of the vehicle to facilitate service. A manual override with an ergonomic deployment method shall permit use of either ramp system in the event of a failure without the use of tools. All major ramp components including the ramp plate shall be made of stainless steel. Front door and streetside rear door ramp systems shall be of the same size and configuration with standardized componentry for ease of maintenance. The ramp unit shall be a cartridge style replaceable within 30 minutes by an Authority trained mechanic.

Streetside rear door ramp system shall have a secure control panel located at the rear doors for bus operator use. The panel shall have a cover with a keyed panel cam lock to prevent unwarranted access. All buses shall be keyed alike and the Contractor shall provide ten keys with each bus at time of bus delivery. The Contractor shall provide thirty keys with the delivery of each pilot bus.

The street side rear door ramp system shall have a primary activation switch in the operator's compartment. Activation of the primary switch by the bus operator shall actuate the interlock system and provide power and an enable signal to the rear door ramp control panel.

(Table 2, D25)

TS 71.2 Mobility Device/Wheelchair Accommodations

Two forward-facing locations, located adjacent to the front entrance door ramp system (as practical), shall provide parking spaces and securement systems compliant with ADA requirements for passengers who are using a mobility device or wheelchair. **(Table 2, D25)**

TS 71.3 Interior Circulation

Maneuvering room inside the bus shall accommodate easy travel for passengers using a mobility device/wheelchair from any ramp to the securement area. As a guide, no width dimension should be less than 34 in between fixed objects. Areas requiring 90° turns of wheelchairs, such as the front vestibule and streetside rear door vestibule, must have a clearance arc dimension no less than 45 in., and in the parking area where 180° turns are expected, space should be clear in a full 60 in. diameter circle. A vertical clearance of 12 in. above the floor surface must be provided on the outside of turning areas for wheelchair footrests.

Securement areas shall be designed so that no portion of passengers using a mobility device/wheelchair or the device itself protrudes into the aisle of the bus when parked in the identified parking space(s). When

the positions are fully utilized (based upon a standardized 30 x 48 inch mobility device/wheelchair), an aisle width of no less than 22 in. shall be maintained. **(Table 2, D25)**

TS 71.4 Securement System

Two (2) forward-facing securement areas shall provide parking spaces and securement systems compliant with, and exceeding ADA requirements, for passengers using mobility devices/wheelchairs. The securement areas must be easily accessible for passengers in wheeled mobility devices from the front door and streetside rear door ramps. The primary securement area position shall be on the street side of the bus directly behind the wheel tub. Each securement area shall be a minimum of 30 × 48 in. To provide greater maneuverability in the securement area, the Authority wishes to explore an increase in length from 48 in. to 54 in. In a minimum of one of the three proposed seating arrangements, presented for Authority review, the Contractor shall provide an alternative seating arrangement with this increased dimension in the securement area. **(Table 2, D25)**

The securement system shall be an integral part of the vehicle seating. The securement area seating design shall be of fold-up convertible seating units located as close to the wall as possible, to minimize the amount of passenger seating losses, maximize aisle width, provide mobility device access to either position when any position is occupied, provide a safe securement for passengers who use mobility devices, and allow for a quick and easy-to-use securement system for assistance by bus operators. The securement system shall include a three (3) point lap and shoulder occupant restraint belt and four (4) mobility aid securement belts optimally placed for stability and adaptable for the widest range of equipment. Release handles for the securement straps shall be readily accessible when any mobility device is properly secured in the securement area.

Four (4) Q'STRAINT 14" securement loops (part number Q5-7580) are to be provided for each wheelchair securement area. The securement system shall be A.R.M. restraint system by American Seating or Authority approved equal. This system shall comply with the strength and free movement criteria of the ADA accessibility guidelines for transportation vehicles; final guidelines per regulation 36 CFR part 1192 and conforming to all applicable FMVSS. **(Table 2, D25)**

XIV. SIGNAGE AND COMMUNICATION

TS 72. Destination Signs

A destination sign system shall be furnished on the front, on the curb side near the front door, and on the rear of the vehicle. The sign system shall be amber LED, of the latest service proven Luminator-TwinVision configuration or approved equal.

All signs shall be controlled via a single interface (reference TS Attachment 4 for system integration). The sign system shall be programmable by means of a USB style, fast upload connection or Authority approved equal.

All exterior destination signs shall display the ESS SoC while the bus is connected to a high voltage charger. The SoC shall display whether the master run switch is 'off' or in any 'run' position.

The sign system shall also be programmable remotely without the need to physically visit the bus. The manufacturer may choose to make this possible with an integration of the cellular gateway (see TS 76.8) with the sign, or an integration of the Intelligent Transportation System (see TS 76.3) with the sign, or by another means as approved by the MBTA. The communication of data necessary for such an integration can use a dedicated cable, such as an ethernet cable, or another means as approved by the MBTA.

The signs shall accept programming created in the Luminator-TwinVision MIE already in use by the MBTA. They shall not require the MBTA to configure sign layouts in software that the agency is not already using for its existing Luminator-TwinVision signs

The destination sign compartments shall meet the following minimum requirements:

1. Compartments shall be designed to prevent condensation and entry of moisture and dirt.
2. Compartments shall be designed to prevent fogging of both compartment window and glazing on the unit itself.
3. Access shall be provided to allow cleaning of inside compartment window and unit glazing.
4. The front window shall have an exterior display area of no less than 8.5 in. high by 56 in. wide.
5. The front window shall have a defroster grid operating in conjunction with the bus defroster system

Interior Message Signs (VMS) shall meet the requirements of TS Attachment 4 (Section E). The Contractor shall provide Destination Sign installation and configuration documentation, interface and system integration (per TS Attachment 4, and a VMS installation and glare/reflection analysis per TS Attachment 4 (Section E) as part of (**CDR 14**)

TS 73. Passenger Information and Advertising

TS 73.1 Interior Displays

Provisions shall be made on the rear of the driver's barrier or equipment box located on the wheel well for a frame to retain information such as routes and schedules.

Advertising media 11 in. high and 0.09 in. thick shall be retained near the juncture of the bus ceiling and sidewall. The retainers may be concave and shall support the media without adhesives. The media shall be illuminated by the interior light system. **(Table 2, D29)**

TS 74. Passenger Stop Request / Exit Signal

A passenger "stop requested" signal system that complies with applicable ADA requirements defined in 49 CFR, Part 38.37, shall be provided. The system shall consist of a touch tape, chime, and interior sign message. The touch tape shall be accessible to all seated passengers, with provisions for standees. It shall

be easily accessible to all passengers, seated or standing. Vertical touch tape shall be provided at each window mullion and adjacent to each securement area and priority seating positions. The touch tape (including WC area activation pad) shall require an actuation force of no more than five pounds.

Heavy-duty "stop request" signal buttons shall be installed on all vertical stanchions, including modesty panel stanchions. Buttons shall be flush to the switch housing and clearly identified as "STOP."

The Contractor shall provide a toggle switch in a discreet location for use by Authority bus maintenance personnel that will expedite testing of chime switches. Activation of the switch will negate the requirement of cycling the bus doors each time a chime strip is tested.

(Table 2, D29)

TS 74.1 Signal Chime

A single "stop requested" chime shall sound when the system is first activated. A double chime shall sound anytime the system is activated from mobility device/wheelchair securement areas. All chimes shall sound completely before the voice announcement system engages.

Exit signals located in the mobility device/wheelchair securement areas shall be no higher than 4 ft. above the floor. Instructions shall be provided to clearly indicate function and operation of these signals. **(Table 2, D29)**

TS 75. Data Communications (DRS 28)

TS 75.1 General

All data communication networks shall be either in accordance with a nationally recognized interface standard, such as those published by SAE, IEEE or ISO, or shall be published to the Authority with the following minimum information:

1. Protocol requirements for all timing issues (bit, byte, packet, inter-packet timing, idle line timing, etc.) packet sizes, error checking and transport (bulk transfer of data to / from the device).
2. Data definition requirements that ensure access to diagnostic information and performance characteristics.
3. The capability and procedures for uploading new application or configuration data.
4. Access to revision level of data, application software and firmware.
5. The capability and procedures for uploading new firmware or application software.
6. Evidence that applicable data shall be broadcast to the network in an efficient manner such that the overall network integrity is not compromised.
7. Complete definition files in .dbc or other appropriate format for all communications messages of all systems on the bus networks

Any electronic vehicle components used on a network shall be conformance tested to the corresponding network standard.

The bus shall be equipped with a data logger monitoring J1939 system. The Contractor shall provide software to permit the Authority to review live data, record data, review faults, and generate custom reports.

All data and communications systems and systems integration shall follow cybersecurity best practices and V-model per the latest revision of ISO/SAE 21434. (CDR 7)

TS 75.1.1 Software Revision and Version Control

The Contractor shall utilize a robust Software Version Control (SVC) system to ensure all bus systems, components, and levels (TS 32) have the latest and identical software revision. Any software revisions made during production and warranty periods shall be promptly incorporated on all buses by the Contractor. The Contractor shall also update any diagnostic software and programs on all diagnostic tools provided under this Contract during production and warranty periods. (Refer to TS 79 and RFP 10.21 Software Configuration Control for additional software requirements)

TS 75.2 Propulsion System Level

Propulsion system components, consisting of the drive motor(s), motor inverter(s), cooling system, HVAC system, ESS battery management, energy storage system, anti-lock braking system, and all other related components, shall be integrated and communicate fully with respect to vehicle operation with data using SAE Recommended Communications Protocols such as J1939 and/or J1708 / J1587 / J1292 with forward and backward compatibilities or other open protocols. At a minimum, propulsion system component systems shall be powered by a dedicated and isolated ignition supply voltage to ensure data communication among components exists when the vehicle ignition is switched to the "on" position. These systems shall communicate at a minimum baud rate of 500 kilobits-per-second (kbps).

TS 75.2.1 Diagnostics, Fault Detection and Data Access

Propulsion system performance, maintenance and diagnostic data, and other electronic messages shall be formatted and transmitted on the communications networks.

The propulsion system level shall have the ability to provide continuous monitoring, record abnormal events in memory, enable the generation of Authority accessible and designed custom data reports, and provide time stamped diagnostic codes, provide related fault tree analysis, and other information to Authority service personnel using laptop compatible software provided by the Contractor. The network level shall also provide live / fail status, current hardware serial number, software / data revisions and uninterrupted timing functions.

TS 75.2.2 Programmability (Software)

The propulsion system components shall be programmable by the Authority with limitations as specified by the subsystem Supplier. Component and subsystem manufacturers and suppliers/Subsuppliers shall not configure bus mounted equipment for wireless updates, unless approved by the Authority during the design review process.

TS 75.2.3 Multiplex Level

The Multiplex system shall be configured with a programmable timer to keep the bus in 'sleep mode' while providing power to certain systems/accessories after the bus is shut off. The Contractor shall provide the Authority with sufficient equipment, system access, and training, to permit Authority control of sleep mode time and addition and/or subtraction of systems/accessories active during sleep mode.

TS 75.2.4 Data Access

At a minimum, information shall be made available via communication ports on the multiplex system. The location of the communication ports shall be easily accessible with locations in the front of the bus near the operator's seat, motor/drive unit compartment, and on the roof top near roof mounted systems. The communication port locations shall be subject to review and approval by the Authority.

TS 75.2.5 Diagnostics and Fault Detection

The multiplex system shall have a proven method of determining its status (system health and input / output status) and detecting either active (online) or inactive (offline) faults through the use of on-board visual / audible indicators.

In addition to the indicators, the system shall employ an advanced diagnostic and fault detection system, which shall be accessible via either using laptop compatible software provided by the Contractor or a handheld unit. Either unit shall have the ability to check logic function. The diagnostic data can be incorporated into the information level network or the central data access system.

A mock-up board Training Aid, where key components of the multiplexing system are replicated on a functional model, shall be provided as a tool for diagnostic, design verification and training purposes. This mock-up board shall be component of the Electrical System Training Aid.

TS 75.2.6 Programmability (Software)

The multiplex system shall have security provisions to protect its software from unwanted changes. This shall be achieved through any or all of the following procedures:

1. Password protection
2. Limited distribution of the configuration software
3. Limited access to the programming tools required to change the software
4. Hardware protection that prevents undesired changes to the software

Provisions for programming the multiplex system shall be possible through a laptop. Reference TS Attachment 5, Special Tools & Test Equipment, for design configuration and quantities of laptops to be provided to the Authority. The multiplex system shall have proper revision control to ensure that the hardware and software are identical on each vehicle equipped with the system. Revision control shall be provided by all of the following:

1. Hardware component identification where labels are included on all multiplex hardware to identify components
2. Hardware series identification where all multiplex hardware displays the current hardware serial number and firmware revision employed by the module
3. Software revision identification where all copies of the software in service display the most recent revision number
4. A method of determining which version of the software is currently in use in the multiplex system

Revision control labels shall be physically located near the programming port.

Per TS 79, the Contractor shall provide software configuration control and management services for all bus components and systems software during the pilot and production stages of the procurement, and the fourteen (14) year or 500,000 mile service life of the bus following delivery. **(CDR 25)**

TS 76. Communications

A fully integrated and comprehensive Camera System, Bus Communication System, and Two-Way Mobile Radio System shall be installed on each bus in accordance with TS Attachments 3, 4, and 6 respectively. During the design review process, the Contractor shall review all MBTA systems and equipment requirements and establish a Systems Integration Plan that shall ensure that all systems shall be properly interfaced in the complete bus and shall be fully compatible with the MBTA’s existing

systems. The System Integration Plan shall be submitted at the Initial Design Review meeting for the Authority's review and approval **(CDR 23).**

TS 76.1 Installation Requirements

In line with the Systems Integration Plan, all communications equipment shall be installed appropriately for shock vibration and weather resistance. All communications equipment shall be installed at the manufacturer's production facility and tested for proper functionality and integration. The majority of the equipment should be housed within the electronics locker behind the Operator in a manner as approved by the Authority. Communications Antennas installations including ground planes and wiring shall be provided in accordance with TS Attachments 3, 4 and 6.

TS 76.2 Mobile Radio System

A Mobile Radio System shall be installed on each bus. The mobile radio system shall be fully integrated with the ITS and compatible with the existing MBTA Radio System. The Mobile Radio System shall conform to the MBTA Radio Specification included in TS Attachment 6.

The system shall be installed in conformance to the mobile radio system supplier's instructions. Appropriate system design installation and integration shall be confirmed as part of the Design Review Process and Pilot Bus Review.

TS 76.2.1 Driver's Speaker

Each bus shall have a recessed speaker in the ceiling panel above the driver. This speaker shall meet all requirements for interior speakers in TS Attachment 4.

TS 76.2.2 Handset

Contractor shall install a handset for driver use.

TS 76.2.3 Covert Alarm

Contractor shall install a covert alarm that is accessible to the driver by push button but hidden from view, in an Authority approved location. The covert alarm sends an emergency radio alarm to dispatch and permits covert microphone use. Reference TS Attachment 6 for additional covert alarm system requirements.

TS 76.2.4 Hoodlum Light Switch

Contractor shall install a "hoodlum light" switch that is accessible to the driver but hidden from view, in an Authority approved location located on the floor. The hoodlum light switch activates the hoodlum lights and/or enables destination sign emergency message. The floor mounted switch shall be designed to adequately protect from accidental activation during normal operation and shall be silent when activated.

TS 76.3 Intelligent Transportation System

The MBTA currently utilizes an Intelligent Transportation System (ITS). The ITS encompasses Computer Aided Dispatch (CAD), Automated Vehicle Location (AVL), Automated Vehicle Monitoring (AVM), Public Address (PA) and Vehicle Messaging System (VMS). The Contractor shall provide all equipment associated with the ITS as outlined in TS Attachment 4, "Communications System".

The contractor shall review and confirm with the Authority all integration and interface requirements with the ITS during the Initial Design Review meetings. The fully integrated ITS shall be installed on the pilot bus for evaluation during the 30 day testing and demonstration program. The Contractor shall be responsible for the integration, installation and testing of the ITS on every vehicle prior to delivery to the Authority.

The manufacturer may choose the ITS as the means by which to enable the MBTA to program the destination sign remotely, but it is not the only option – see TS 76.

The ITS equipment shall be fully compatible with the MBTA's existing ITS and shall not add steps to the administration of the system, except as necessary to support destination sign programming if applicable, without the approval of the MBTA.

The ITS integrates with other systems on board the vehicle using the VLAN or other connections, including the radio (TS 76.2), the destination sign (TS 72), automated passenger counters (TS 76.7), and high voltage battery management system (TS 8.7). The communications protocols of any such integration shall be fully documented and the documentation provided to the MBTA.

TS 76.3.1 ITS Cellular Connectivity

The ITS shall be able to transmit real-time data between the on-vehicle (e.g., VCU) and back-end (i.e., servers located at the MBTA's data center) system components via the Camera Surveillance System cellular internet router (Camera Router) in addition to radio-based data communication (TDMA). All radio-related system functions (e.g., requests-to-talk) should continue to operate solely over TDMA unless otherwise agreed to by the MBTA.

Communication between the ITS Controller and the Camera Router shall be via a wired ethernet connection or another mechanism agreed to by the MBTA. The MBTA shall be able to disable this functionality in software, in which case all real-time on-vehicle to back-end data communications shall occur via TDMA.

With the approval of the MBTA, an alternate mechanism of communication between the front-end and back-end ITS components may be provided.

TS 76.4 Wireless Local Area Network (WLAN)

The vehicle WLAN component is embedded in the ITS Controller™ and enables high-speed communications to and from the vehicle using the IEEE 802.11b and 802.11g standards. Onboard data is stored in the ITS Controller™ non-volatile memory. During vehicle power up or down sequences, a connection is made automatically with the IP-based FTP server. Data is then uploaded from the vehicle and stored on the server for integration and summarization into the TransitMaster™ database. WLAN is used to transfer data to and from the vehicle fleet including:

1. Upload to Vehicle
    a) Route and schedule files
    b) Canned message updates
    c) ITS Controller™ software updates
    d) Automated annunciation system announcements
    e) Vehicle configuration modifications
2. Download from Vehicle
    a) Vehicle diagnostic information
    b) Automatic passenger count information
    c) Stored operational messages
    d) ESS SoC and SoH

TS 76.5 Vehicle Local Area Network (VLAN)

The Contractor shall install and verify the operability of a Vehicle Local Area Network (VLAN) in accordance with SAE Recommended Practice J1939, Serial Data Communications Between Microcomputer Systems in Heavy-Duty Applications, SAE Recommended Practice J1587, Joint SAE/TMC Electronic Data Interchange Between Microcomputer Systems in Heavy-Duty Vehicle Applications and SAE Recommended Practice J2496, Transport Area Network Cabling. The VLAN shall initiate from the Electronics Locker and have Device Access Boxes in strategic locations throughout the bus identified by the Authority.

The VLAN shall provide the inter connectivity of all elements of the Bus Communication System, and all other equipment on the bus with microprocessor controls. Functionally, the VLAN shall support an environment where all components, modules, and systems installed on the bus shall have built-in diagnostics capability. The diagnostic system shall be capable of checking the communications between all components of the installed systems by Authority technicians.

TS 76.6 Camera Surveillance System

The Contractor shall provide all wiring and mounting locations for a multi-camera surveillance system, including the installation of cameras, recorder, etc. in line with the requirements of TS Attachment 3, "Mobile Closed Circuit Television System". The camera system shall be the latest configuration offered by Genetec (or Authority Approved Equal) and shall be fully integrated with the existing MBTA Bus Communications System.

If a door interlock is active and the parking brake is not set, an alarm shall be sounded if the operator leaves the seat. When the operator is not seated and the parking brake is released, and ignition/propulsion is either on or off, an alarm and audible annunciation warning message shall be activated (TS 40.6). These events shall be broadcast on the VLAN to trigger a video record event five (5) minutes before and after the event.

As noted in TS 76.3.1 the cellular router used by the Camera Surveillance System shall also be used to enable cellular communication between the on-vehicle and off-vehicle portions of the ITS unless another approach to real-time cellular communications is agreed to by the MBTA.

TS 76.7 Automatic Passenger Counter (APC)

An APC system, manufactured by Urban Transportation Associates (UTA) or approved equal, shall be installed on each bus.

The APC system monitors passengers entering and exiting at both vehicle doorways. Entering and exiting counts are collected and a formatted message is transmitted via the Vehicle Local Area Network (VLAN) to the vehicles existing GPS/AVL location system. The merged APC data is then sent to the APC server through a Wi-Fi connection. The APC OEM shall provide appropriate system integration support as well as installation/debugging support as required.

The APC system design and installation proposal shall be reviewed during the Design Review Process, undergo a proper design review process and is subject to Authority review and Approval. The APC system shall be fully integrated with the Authority's existing ITS **(Table 2, D23).**

TS 76.8 Cellular Gateway

A Samsara VG34-M vehicle gateway is to be installed and tested in each bus. The contractor shall be responsible for connection to the VLAN, appropriate integration of the gateway, antenna, and all associated wiring into the vehicle. The cellular gateway monitors vehicle telemetry data (TS 76.8.3), vehicle location, maintenance data, and other vehicle state data described below and transmits it via cellular to vendor-supported environment from which it is available via low-latency (real-time at a frequency of no more than 4 seconds) API. The cellular gateway shall be capable of providing an 802.11g Wi-Fi network but shall be delivered in a configuration such that no such network is active. The cellular

gateway shall also support a wired ethernet input for internet connectivity, but this shall also be delivered not connected to any on-board equipment.

The cellular gateway shall be powered for no less than 24 continuous hours by a Contractor provided UPS back-up battery in the event of vehicle power loss.

The manufacturer may choose the cellular gateway as the means by which to enable the MBTA to program the destination sign remotely, but it is not the only option – see TS 72.

The Contractor shall be responsible for all cellular gateway license fees, beginning with the delivery of each bus, and running for a one year period.

TS 76.8.1 Cellular Communication

The cellular gateway shall communicate using 5G cellular protocols, or, if no such device is available, 4G cellular protocols. The gateway shall transmit vehicle location, maintenance data, and other vehicle state data described below in real time.

TS 76.8.2 Location Tracking

The cellular gateway shall track the vehicle's position by means of a Global Positioning System (GPS) antenna. In tunnels where no GPS signal is available, and where the MBTA or MassDOT have installed Bluetooth Low Energy 4.1 beacons for the purposes of location tracking, the cellular gateway shall track the vehicle's position by means of those beacons.

TS 76.8.3 Vehicle Telemetry Data

The cellular gateway shall monitor vehicle telemetry and state data from the VLAN. This data must include but is not limited to: ESS SoC, ESS SoH, low voltage system state of charge, individual thermal management coolant temps, propulsion system faults, ABS system faults, power generation faults, vehicle speed, vehicle state (off, on, stationary), odometer, door open/closed status, the sign code currently being shown by the destination sign, APC data, operator badge ID, route number, wheelchair deployment, bus location, and door interlock status.

If a door interlock is active and the parking brake is not set, an alarm shall be sounded if the operator leaves the seat. This event shall be broadcast on the VLAN to trigger a video record event.(Refer also to TS Attachment 3 and TS 40.6)

TS 76.9 Bus Mounted Data Recorder

The Contractor shall install a FLEETWATCH Model JX55 Data Logger and TX55 Transceiver as manufactured by S & A Systems Inc., Rockwall, Texas, in each bus. The Contractor shall be responsible for appropriate integration of the system into the vehicle. Each data logger shall be connected directly to a dedicated J1939 connector near the operator's area on the bus (in apparatus or equipment cabinet). The transmitter shall not be installed on a metal surface of any kind and shall be located in an area above the operator's seated position and line of sight. The Contractor shall program each system at their facility prior to bus delivery.

As part of the Design Review Process, the Contractor shall submit FLEETWATCH system component installation locations, and proposed monitored systems and data, for Authority review and approval consideration. **(CDR 23)**

TS 77. Electronic Noise Control

Electrical and electronic subsystems and components on all buses shall not emit electromagnetic radiation that shall interfere with on-board systems, components or equipment, telephone service, radio, or TV reception, or violate regulations of the Federal Communications Commission.

Electrical and electronic subsystems on the buses shall not be affected by external sources of RFI / EMI. This includes, but is not limited to, radio and TV transmission, portable electronic devices including computers in the vicinity of or onboard the buses, AC or DC power lines and RFI / EMI emissions from other vehicles.

Electronic Noise Control shall meet the requirements of all applicable SAE, ISO, and CISPR standards to include the latest revisions of SAE J1113, SAE J1455, ISO 11451-2, and CISPR 12-10. The contractor shall perform full bus Electromagnetic Interference testing (TS Attachment 2) on the completed, as-delivered pilot bus (es), to demonstrate compliance to TS 5.2.3 , TS 33 , TS 77 . Individual systems requiring off-bus bench testing shall also be performed.

XV. AUXILIARY EQUIPMENT

TS 78. Bike Racks

The Contractor shall mount a brushed stainless steel bicycle rack, Byk-Rak (two-position), Sportworks DL2 S/S, or approved equal, to the front bumper of the bus. The bike rack shall be installed as per the manufacturer's recommendations and shall not impact the bus approach angle.

Appropriate decals shall be installed at the front of the bus to adequately describing the operation of the bicycle rack. Decals and decal location shall be approved by the Authority during the Pilot Bus review.

The bicycle rack shall be designed to carry two bicycles. Each bike can be loaded/unloaded independently of the other.

In the deployed position the bike rack shall latch automatically in position. When not in use the bike rack shall fold upward against the front of the bus and latch securely in place.

The bike rack shall not interfere with the operation of the windshield wipers, lighting, access panels, or front lift tow or flat tow adapters. The bike rack shall be easily removable for seasonal and emergency detachment from the bus. Detachment shall not require removal or disassembly of the front bumper or any other bus mounted parts. Approval of the mounting location and installation shall be provided by the Authority during the Design Review Process. **(Table 2, D29)**

TS 79. Software Configuration Control

In keeping with the requirements of RFP Section 10.21, the Contractor shall provide software configuration control and management services for all bus components and systems software during the pilot and production stages of the procurement, and the fourteen (14) year or 500,000 mile service life of the bus following delivery. The Contractor shall provide the MBTA Project Manager with notification of revisions as they occur and provided scheduled software revision status updates. Software revision notifications shall occur prior to any production installation/update on vehicle systems and shall include:

1. Original and updated software revision numbers
2. Reason for software/program change
3. Description of implemented changes
4. Impacted vehicles affected by the software change
5. Affected software theory of operation for of change

The Contractor shall submit their software configuration control and management services plan during the Design Review Process. **(CDR 25)**

TS 80. Software Escrow

In order to protect the Authority from any issues that may arise regarding software required to operate buses in passenger service, the Contractor shall make arrangements to provide a software escrow that contains all software necessary to operate and make changes to all electronic system contained on the buses for no less than fourteen (14) years beginning with bus acceptance.

The Contractor's escrow policies shall contain an endorsement naming the Authority as an additional insured party and that written notice shall be given to the Authority at least thirty (30) days prior to termination, cancellation or material reduction of coverage in the policy.

As part of the Intermediate Design Review Meeting, the Contractor shall provide a list of all OEM software comprising proprietary works ("Proprietary Software") for all major vehicle subsystems and

vehicle drawings, and a proposed Software Escrow Agreement, for review and Authority approval consideration. .

Source code for the Proprietary Software and all related documentation required for the use and modification thereof, and any revisions or derivative works based on the Proprietary Software developed pursuant to the Contractor's performance of the Contract (collectively, "Escrow Materials") shall be deposited in an escrow account with a third party, as set forth in RFP Section 12.2.8 (1)(d); Software Escrow Agreement. The Contractor shall pay all initial and future costs related to the escrow account. When necessary, and only upon request, information contained within the listed software shall be made available to the Authority through the Contractor and/or OEM of the vehicle subsystem.

The Contractor and OEM are not obligated to provide copies of source code, as this is proprietary intellectual property; however, the Contractor is obligated to assist the Authority with any technical assistance for the duration of the service life of the bus. Such assistance provided by the Contractor shall include software updates, deployment documentation and upgrade compatibility confirmation.

The Contractor shall maintain current versions of all software in escrow and shall ensure all new software revisions and upgrades are provided to the escrow agent. In the event the source code provider files for bankruptcy or fails to maintain or provide necessary software upgrades, the Contractor shall be responsible for developing and providing replacement software. The escrow materials shall immediately be obtainable and usable by the Authority in the event the Contractor fails to support the continued use of the Proprietary Software by the Authority, or upon termination or expiration of the term of the escrow. **(CDR 25)**

XVI. OPTIONAL EQUIPMENT

TS 81. Optional Equipment General Requirement

The Contractor shall provide pricing in the designated area of their bid proposal for the following optional equipment.

TS 81.1 Up to an Additional 415 New Low Floor Battery Electric Buses (Option 1)

Reference RFP 1F-22 Section 1.1 (B)

Configuration may evolve and shall be established from results of Post Delivery Monitoring of the base order fleet, subsequent Post Delivery Monitoring of ensuing Option 1 fleets, and any changes in the Authorities operating environment.

TS 81.2 Up to 415 New Low Floor Battery Electric Buses with Streetside Boarding (Option 2)

Reference RFP 1F-22 Section 1.1 (B)

1. OPTION 2A – Base order of 35 BEBs configured for street side boarding
2. OPTION 2B – Up to 380 additional BEBs configured for streetside boarding. Option 2B will only be exercised if 2A has been exercised.

The Authority reserves the right to exercise through one or more option(s) for furnishing through Option 2 up to 415 new Battery Electric Buses configured for street side boarding as defined in Technical Specification VE21-054 with configuration confirmed by two pilot buses.

Configuration may evolve and shall be established from results of Post Delivery Monitoring of the base order fleet, subsequent Post Delivery Monitoring of ensuing Option 1 and/or Option 2 fleets, and any changes in the Authorities operating environment.

TS 81.3 Energy Storage System (ESS) Extended Warranty (Option 3)

Reference RFP 1F-22 Section 9.3

TS 81.4 Energy Storage System (ESS) Lease (Option 4)

The Contractor shall provide the Energy Storage System (ESS) as a lease throughout the 14 year life of the bus. For the purposes of the lease description, the base Battery Electric Bus configuration and pricing shall be *considered* as sans the ESS; however, the bus shall leave the Contractor's facility fully tested and functional per the requirements of this Technical Specification.

The Contractor's ESS lease plan shall include:

3. Lease period to begin concurrent to the acceptance of individual buses by the Authority
4. Lease term shall be 14 years
    a) All deliverables shall be based upon the individual bus acceptance dates
5. The Contractor shall provide residual value of the ESS to be used as a basis of extending the term of the lease or purchase of the ESS by the Authority at the end of the 14 year lease term
6. The Contractor shall be responsible for all costs related to the disposal of an ESS
    a) Anytime during the 14 year bus service life
7. During the term of the ESS lease agreement, the Contractor shall provide
    a) Monthly reports at a minimum detailing the ESS State of Health (to the cellular level), trip data, and consumption data (to sub-system and component level), charging reports (to include

SoC levels overlaid with trip data). Reports to be submitted for Authority approval during the design review process.

b) Provide ESS component materials (e.g., battery cells, ESS covers, fasteners, all internal ESS components)

c) Provide replacement ESS when WEOL occurs

d) Provide replacement ESS when necessary

8. Provide ESS system upgrades to include ESS revisions, software revisions, etc.
9. Provide sufficient materials and technical support stationed within 25 miles from Boston
10. In the event an ESS requires replacement or repair, the Contractor shall ensure the bus shall not be out of service for more than seven days from the failure date

TS 81.5 Q'Straint Quantum (Option 5)

Each bus shall be equipped with one curbside, rear facing, Q'Straint Quantum wheelchair securement system to include Quantum unit, user interface, driver interface, instrument panel indicators, bus interlock interface, and ADA backrest with occupant belts.

The Contractor shall include a destination sign at the rear door visible from the Q'Straint Quantum position. The destination sign shall be subject to the requirements of Attachment 4, Section E.

The Contractor shall optimize seating layout to meet ADA and Q'Straint Quantum requirements, maximize seating and standee capacity, and maintain the base order boarding requirement of 36 seats. Buses with the streetside boarding configuration option shall accommodate no less than 31 seated passengers.

The user interface shall be located in accordance with the provisions of 49 CFR 38.37

When fully deployed to the maximum extent possible, no portion of the Q'Straint Quantum wheelchair securement system shall protrude into the aisle and interfere with passenger movement, or be a hazard to passengers, or inhibit access by any other mobility device.

TS 81.6 License Plate Recognition System (Option 6)

Each bus shall be equipped with a License Plate Recognition System per the requirements of TS Attachment 8

TS 81.7 Vinyl Exterior Color Scheme (Option 7)

The selected paint scheme for the vehicle shall be digitally printed using 3M MCS certified inks on 3M Envision Print Wrap Film SV480Cv3 and shall be laminated with 3M Envision luster Wrap Over laminate 8549L.

All decals and placards shall be manufactured as per Authority supplied specifications in TS Attachment 1 and applied over the vinyl wrap.

The vinyl wrap shall be guaranteed for (7) years from acceptance of the bus.

The Contractor shall provide the Authority with a written/electronic copy of the installation procedure and adhesion test procedure prior to the first installation. The Authority shall have all rights to use the documentation for internal training and other internal uses.

The Contractor shall submit a proposed "*Roadside Repair Kit*" consistent with TS Attachment 1 during the Design Review Process. The *Roadside Repair Kit* shall be used by Authority personnel to make localized cosmetic repair to damaged bus exterior panels.

TS 81.8 Tire Pressure Monitoring System (Option 8)

The bus shall be equipped with a service proven electronic tire-pressure monitoring system. The pressure monitoring system shall illuminate a dash lamp to inform the driver when any of the bus tires are outside of the allowable pressure range. The pressure monitoring system shall be capable of transmitting a discrete signal to the Authority's Operations Control Center, through the vehicle communication system.

TS 81.9 Passenger Compartment Antimicrobial Surface Treatment (Option 9)

If awarded, the Contractor shall provide an antimicrobial surface treatment for all high touch areas including passenger seating, stanchion, grabrail surfaces, driver's safety barrier, and all entrance and exit doors and door handles. The EPA registered antimicrobial treatment coating shall be non-toxic, environmentally friendly, and shall not damage or discolor surfaces. The Contractor shall provide the initial application and any reapplications required to maintain a 95% efficacy throughout the first seven years of each bus's service life.

The treatment coating shall have undergone ISO 22196 testing on equivalent transit bus surfaces throughout the full range of heat and humidity in the Authority's operating environment for Staphylococcus aureus, E. coli, and SARS-CoV-2, with no less than 95% reduction in each bacteria and virus.

The Contractor shall provide full documentation of test reports confirming efficacy results for the required surfaces, EPA registration documentation, and antimicrobial exposure analysis of the proposed coating. The Contractor shall also provide a reapplication schedule and documentation of efficacy longevity validating the proposed schedule.

TS 81.10 Mobileye Advanced Driver Assistance System (Option 10)

If awarded, the Contractor shall provide, install, and fully integrate a Mobileye *Shield+ V4* Advanced Driver Assistance System (ADAS) into each bus per the requirements of TS Attachment 9.

TS 81.11 Dual-sided LCD Passenger Information Screen (Option 11)

If awarded, the Contractor shall provide, install, and fully integrate, on the pilot buses and 8 production buses (ten buses in total), a dual-sided LCD passenger information screen that allow for display of real-time passenger information and advertising per the requirements of TS Attachment 10.

TS 81.12 Geofencing System (Option 12)

If awarded, the Contractor shall provide, install, and fully integrate a Geofence system that shall disable the auxiliary heater when in diesel mode, thereby providing for zero-emissions operation. Additionally, the geofence system shall limit speeds in areas designated by the Authority.

The Geofencing system shall require no input from the vehicle operator during routine use, however, a momentary switch located in the operator's compartment shall allow for Geofence system override. The Auxiliary Heater Diesel Mode Geofencing System shall be able to enable, disable, or automatically enter the vehicle into an extended auxiliary heater diesel "off mode" if all required operating conditions are met.

Geofencing in facility 'yards' and other locations shall improve safety by limiting vehicle speed.

The Geofencing system shall have an interface that can be utilized by the Authority to modify the locations and operating conditions. The system shall also incorporate features that ensure that the vehicle location continues to be tracked even in difficult environments where satellite signals may not be present. The Geofencing system shall be configurable by the Authority and updates sent to the fleet wirelessly. The software and all systems licenses required to implement this Geofencing system shall be included in the cost of the bus for seven years from the acceptance date of the last delivered bus.

Geofence system shall be subject to review during the design review process with systems testing and validation performed by the Contractor on the pilot bus during pilot bus testing at the Authority.

TS 81.13 HVAC System with Heat Pump (Option 13)

If awarded, the Contractor shall provide, install, and fully integrate a HVAC system utilizing heat pump technology to reduce ESS consumption and extended BEB range. The proposed system shall meet all requirements of TS X *Heating, Ventilating and Air Conditioning* and warranty provisions of RFP 1F-22.

The Contractor shall provide with their:

1. HVAC system with heat pump theory of operation
2. Comparison of maintenance requirements of HVAC system with heat pump against TS Section X system
3. Refrigerant type
4. Analysis of BEB passenger compartment thermal loading in the extremes of the Authority operating environment and with passenger counts of 25%, 50%, 75% and 100% gross load
5. ESS consumption comparison between TS Section X HVAC system to proposed HVAC System with Heat Pump for each scenario in bullet 4 above
6. ESS consumption analysis per (5) above with and without a diesel auxiliary heat, and with and without any auxiliary heater
7. Weight comparison of TS Section X HVAC system to proposed HVAC System with Heat Pump